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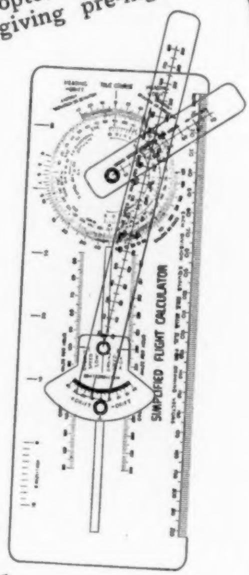

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INTRODUCING THE CONTRIBUTORS

SHERWOOD L. WASHBURN ("Thinking about Race") is Assistant Professor of Anatomy at the College of Physicians and Surgeons, Columbia University. He believes that knowledge of the real differences on which racial classifications are based is a safeguard against the assumption of differences that do not exist, and he is attempting to disseminate such knowledge.

VLADO A. GETTING ("Tropical Diseases in New England") began his affiliation with the Massachusetts Department of Public Health in 1937 as assistant epidemiologist. After serving successively as epidemiologist, assistant district health officer, and district health officer, he was appointed Commissioner of the Department in 1943. Since 1939 Dr. Getting has been on the Faculty of the Harvard Medical School and the Harvard School of Public Health.

R. WILL BURNETT ("Conservation: Focus or Incident in Education") is Assistant Professor of Education at Stanford University and Director of Science Curriculum, Menlo School and Junior College. He is physics instructor for the Army Special Training Program at Stanford, and has assisted in the preparation of material for Pre-Induction Training for the War Department.

HEBER ELIOT RUMBLE ("The Origin of Science Teaching at the Junior High School Level") is a high school principal whose particular interests are in science education and in extra-class student activities. For a number of years he was Chairman of the Science Department and Director of Visual Aids at the Champaign Junior High School, Champaign, Illinois.

ROBERT H. HEIDEL ("A Comparison of the Outcomes of Instruction of the Conventional High School Physics Course and the Generalized High School Senior Science Course") served last year in the War Department, Signal Corps, in Dayton, Ohio, and this year is instructor in physics at Iowa State College.

JAMES D. TELLER ("Humanizing Pre-Flight Aeronautics") has been concerned with the meaning and teaching of "scientific method." His efforts have been largely devoted to the preparation of aids to encourage teachers to "humanize" their teaching of science, and to the construction of instruments for the evaluation of some of the objectives of science teaching that are closely related to "scientific method."

THEODORE D. BENJAMIN ("Your Ally, the English Teacher") teaches physical science and supervises aeronautics instruction at the Bronx High School of Science, New York City. He is a member of the school's "Integration Committee," of which his co-author, ISABEL S. GORDON, is chairman. Dr. Gordon, an English teacher, has given much thought to the problem of organizing students' experiences so that their work in all subjects will contribute to their understanding of certain areas of living, and of doing this in such a way that the advantages usually considered to be those of a traditional high school curriculum are not sacrificed.

CHARLOTTE L. GRANT ("Some Evaluation Instruments for Biology Students") is an instructor in botany and biology in the Arsenal Technical Schools of Indianapolis and a lecturer at Butler University. Her scientific research has been in the fields of ecology and plant pathology; among her educational interests are the teaching of ecology, economic biology, and conservation. ELSA MARIE MEDER, co-author with Dr. Grant, has been concerned with the preparation of evaluation instruments, especially those designed to measure progress toward noninformational objectives, and with the logic basic to test construction.

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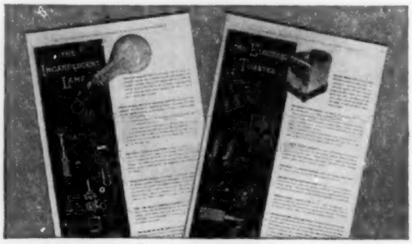

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SCIENCE EDUCATION

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THINKING ABOUT RACE

S. L. Washburn

College of Physicians and Surgeons, Columbia University, New York

RECENTLY the subject of race has been lifted from comparative obscurity to the headlines. Nazi racists have asserted the fabulous superiority of one race, while the Japanese have claimed preëminence for their quite different physical type. On the other hand, people appalled by Nazi misuse of the idea of race have made nearly as absurd claims about the nonexistence of varieties of Homo sapiens. For example, a recent paper started by claiming that there are no differences of functional importance between living races, and proceeded in the same paragraph to proclaim the value of dark pigmentation to people in the tropics.

It is extremely difficult to try to give an unbiased presentation when emotions are involved. Therefore in this paper I have tried to present ways of thinking about race rather than any particular classification. I hope that the methods outlined will aid the reader in evaluating any racial system and will help to clarify ideas concerning race.

In the first place, as has been repeatedly stated, races are groups which are distinguished on the basis of inherited anatomical characters. Race has nothing to do with language, religion, nationality, or social habits. Race is an expression of nature (inheritance), not nurture (learning). Tozzer (1931)* has given an excellent account, well worth the attention of anyone wanting more information on this fundamental point. Psychological differences between races are probably nonexistent, according to Klineberg (1935) who has made an exhaustive study of this subject.

Since racial classification is an anatomical conception, one might think that anatomy would play a large part in discussions of race. Actually the extent to which race has been discussed recently with almost no mention of anatomy is surprising. For example, Klineberg *(op. cit.)* in the section of his book devoted to the "Biological Approach" to race, pays little attention to fossil man, the antiquity of races, or the work of any recent anatomists.

The danger of discussing race without really trying to understand the anatomy of the situation is that one's examples will be irrelevant and one's logic faulty. As an example of faulty reasoning take the current statement that there are no important differences between races because all races intergrade. This is like saying that there are no differences in intelligence because there is a continuous distribution from the lowest to the highest IQ.

The best way to understand race is by a

* References to the literature are cited at the conclusion of this article.

direct approach to the facts,[1] that is, to the study of fossil man, comparative anatomy, and the purposes and methods of classification. It is with these that this paper deals.

THE NATURE OF RACIAL CLASSIFICATIONS

The descriptions of the various races may be regarded as a series of guidebooks to the anatomy of man. Following the guidebook analogy, the content of the whole series of books equals present knowledge of comparative human anatomy. Since the subject matter of this series of books is continuous, the beginning and end of each volume is arbitrary, being determined by convenience. This guidebook series is a useful way of sorting and cataloguing anatomical information, and the descriptions which the books contain were written to answer questions which arose in man's quest for knowledge and understanding.

The practical value of the anatomical descriptions which the books contain will become clearer as they are used. For example, we find that the volume entitled "Europeans" is especially useful because there are over 700 million people to whom this guide applies. The volume on "Mongoloids" includes over 600 million people. These two guidebooks alone describe two-thirds of the people in the world, and, therefore, they are the most useful ones we have. There is another book called "African Negro" which covers some 100 million. Then there are a number of slim volumes which describe types anatomically distinct enough so that it is useful to have separate guidebooks for them, but which are not numerous. Two such volumes would be called "Australian-Melanesian" and "Bushman-Hottentot."

Still there would be a great many people for whom no guidebook is available. Some of these are put in appendices or special chapters. Some have been shifted about when new information showed that they would fit better in a different volume. Migrations and subsequent crossing are creating new situations which the old volumes did not cover. The guidebooks, of course, will need constant revision to keep them up to date.

The usefulness of racial descriptions depends on the fact that the majority of the people in the world can be easily classified. There are intergrades between the types, but these people are less numerous than those to whom the descriptions apply. It should be remembered that classifications are not objective orderings of pure knowledge but are made by men for some purpose. Racial classifications are made by men who are trying to understand human anatomy. Since anatomical classifications have been made by many men in different periods, a brief account of the history of attempts to classify man will prove useful. In each era we will be concerned with purposes and methods rather than nomenclature, because the names of races are only symbols for describing results.

The earliest racial classifications were the result of the discovery that there was a variety of different kinds of men living in different parts of the world. These long antedate Darwin and the rise of evolutionary thought. Since these classifications were based on pictures and what travellers saw, they were superficial and used such traits as color and hair form only. Scientists saw that the populations in various parts of the world were different and sought to give a few characters by which the different peoples could be recognized. The purpose of these classifications was to give a key to the varieties of man. The method was to group like with like as any keen observer could do without special training. Since the vast majority of people believed in special creation and since the races of the world were so incompletely

[1] See Cobb (1943), "Education in Human Biology: An Essential for the Present and Future."

known that they appeared discrete, the races were described as separate species.

The second stage in the history of anatomical classifications arose in the latter part of the nineteenth century under the influence of Darwinian evolution. The purpose of the classification of this period was to describe the evolutionary history of man. The method was that of detailed anatomical comparisons. Bodies of individuals in different parts of the world were dissected. Great osteological collections were built up. It soon became apparent that words like "tall," "short," or "broad" led only to confusion, so various systems of measurement were introduced. These became the basis of modern physical anthropology.

This second era marks enormous advance over the first from the standpoint of both ends and means. However, the scientists of this era knew nothing of genetics or of parallel or convergent evolution, and few fossil men had been discovered. Also before the use of radioactive minerals, the geological time scale was very short. The age of the world was supposed to be only a few thousand years.

The present era is hard to characterize briefly, because it is difficult to keep a perspective on one's own time. The main differences between this and previous eras lie in the abundance of all sorts of data and the kind of theoretical approach made possible by advances in biology and related sciences.

The primary aims of recent classifications are the same as those of the earlier ones. The first is to describe various people of the world in superficial terms. The purpose of this sort of description is to destroy intellectual isolationism. One wonders how many of our soldiers in the Far East had any idea of Polynesians, Melanesians, or aboriginal Australians before they went there. Some of these people seem very different and queer when one meets them for the first time. The best way to keep one's perspective is to have a good idea of the different races before being plunged into the midst of a foreign people.

Granted that it is desirable for citizens in a democracy with commitments all over the world to have some idea about the physical characters of the peoples of the world, how is this end to be accomplished? It is impossible to consider each of the two billion persons in the world. Therefore some system of sampling is necessary. It happens that mankind does divide into great groups, so that a relatively small number of individuals may substitute for the entire group. One Bushman looks more like the next Bushman than either looks like a European or a Mongolian. There is a great variation in each group. Races intergrade and mix. Nevertheless, at present there is no other practical method of obtaining some superficial acquaintance with what mankind is like from a physical point of view. The racial classification is a *simple sampling system* which allows a student to become familiar with the superficial physical characters of two billion people in a remarkably short period of time.

Existing races are the products of evolution, and a second aim of classification is to determine the relations of various races to fossil men and ultimately to other primates. The methods necessary for this purpose are very different from those which were adequate for the first. An understanding of comparative human anatomy is essential. Since fossils consist of bones and teeth only, knowledge of these parts is particularly important. Studies of the different proportions of the body are best carried out according to biometric methods. Genetics, particularly of the blood groups, is playing a larger and larger part in studies of the living.

The utility of the classification which has resulted from intensive anatomical and metrical studies is very great, and only a few examples can be cited here. It has made possible the determination of man's place in nature with an ever-increasing

accuracy. It has served as an aid in historical reconstructions, as in determining the way in which the New World and Oceania were populated. It is of constant use in the anatomical laboratory where subjects of different races are dissected. For example, the facial muscles of the European, African Negro, and Mongolian are quite different (Huber, 1931). This is so much the case that the student following the description of the European, which is in all the textbooks, may become confused when dissecting non-Europeans. There are numerous differences in the muscles and other soft parts, as summarized by Loth (1931), and in the proportions of the body and the skeleton (Martin, 1928). Pelvic shapes differ, and this has a practical application in obstetrics (Caldwell, Moloy, D'Esopo, 1934 and 1938). Limb proportions differ enough to affect the sizes of uniforms (Davenport and Love, 1921). Steggerda (1942) has shown the advantage of using separate height, weight, and age tables for different racial groups.

The more global our national interests become the more use will be found for knowledge of the anatomical characters of races. When there are more medical schools in China or Africa, undoubtedly anatomy textbooks will be written which apply more directly to these peoples.

In summary, the comparative anatomist or physical anthropologist cannot operate without racial classifications because these bring order out of the otherwise meaningless range of human variation. However, these are anatomical classifications which are used for anatomical purposes. Since the ends are anatomical in nature, the methods used are anatomical. There is no thought of leaping from anatomy to intelligence, language, or religion. A scientist takes the most direct route possible. If one wants to know about intelligence, intelligence should be measured, not cranial capacity. If one wants to know about language, language should be studied, not head form. One gets out of a mill only what goes in, although the form may have changed. When anatomy goes in, only anatomy comes out.

THE ANTIQUITY OF RACE

How shall we regard the races of man? Have they been relatively independent for millions of years or are they modern? It used to be thought that the races represented relatively fixed types, some of which were much more closely allied to the apes than others. If any of the living races is particularly primitive, it should be traceable far back in prehistoric time. How far back can the major living races be traced?

The skeletal remains which belong to the living races are found back through the Neolithic period (Polished Stone Age, earliest agriculture). Prior to that the situation was different. In Europe the round-headed people appeared near the end of the Old Stone Age. In Africa none of the early skeletal remains is typically Negro. In Asia Mongoloids seem to belong to late geologic time, but data are exceedingly scanty. As we go back in time, the picture is one of change.

The appearance of the modern races only a few thousand years ago is so sudden that theories have been developed to account for it. This sudden appearance may be partly illusory. Skeletal remains are all that are available, and the soft structures, which are not preserved, may have been more differentiated. Also data are lacking from vast areas, and so earlier representatives of the modern racial types may yet be discovered in these places. It has been argued that the races must be very old to account for the degree of difference seen today, but rather than follow logic alone let us see what the men were like who lived in the latter part of the Old Stone Age.

In Europe (several remains of the Aurignacian period), in Africa (Boskop,

Springbok), in Java (Wadjak), and in Australia (Talgai, Cohuna),[2] there have been discovered skulls and skeletons which all belong to the species of modern man, Homo sapiens. Their limb bones are typically modern. They had, on the average, larger jaws, teeth, and brow ridges than living men but were not beyond the range of variation of living races. Here there is definite evidence of modern man spreading out over the world before the living races are recognizable. All these fossils seem to be of approximately the age of the latter part of the last Ice Age, twenty to fifty thousand years ago. Of course, dating is subject to great error. At least it can be said that they are much older than the earliest finds that can be assigned to living races, and much later than the groups of ancient men to be considered.

In the Americas the evidence of early modern man is not as clear as in the Old World. The earliest finds (Minnesota, Lagoa Santa, Punin; see Roberts, 1943) differ from the later ones, and evidence seems to be accumulating that the men who first entered the New World some 25,000 years ago were a long-headed early type of modern man.

Here is a commonly accepted hypothesis which will cover the main facts of the last phases of man's evolution. Somewhere in the Old World about fifty thousand years ago a generalized type of modern man developed. Variations of this type spread out over the Old World and, somewhat later, into the New. The groups that spread were small parties of hunters. It has been estimated that there were not more than seven million people in the whole world at the hunting and gathering stage of cultural evolution. Therefore, these groups lived in extreme isolation. This isolation made an ideal setting for the development of the local varieties which are called races today.

Each of the major racial groups is characteristically located in one area of the world. The Whites, originally, were located in Europe, the Mediterranean area, and the Near East. The center of Negro development seems to have been in the Congo and West Africa. The Bushmen occupied South Africa and formerly a good deal of East Africa as well. The Australian-Melanesian group occupied Australia, New Guinea, and adjacent islands. The Polynesians were late comers to the island area (the era of the great migrations seems to have started about A.D. 800). The Mongoloids were located in Eastern Asia and migrated into the Americas where they probably absorbed the earlier type of Upper Palaeolithic man.

If such an hypothesis is correct, as many scientists think, the area where the greatest mixing has occurred and which is hardest to classify should be the most central one, that is, India.

Dispersal followed by the establishment of local varieties has been called adaptive radiation. It has been shown to apply to numerous mammalian groups and seems to apply equally well to man (Howells, 1942). However, after the dispersion of modern man, the development of agriculture and the enormous subsequent increase in population soon changed matters. Childe (1939) has written a most stimulating book on the relation of civilization to population. The population of the world increased from some seven million in the hunting stage to over two billion at the present time. As far as race is concerned, the result of this enormous increase has been the loss of biological isolation (Howells, *op. cit.*). Small numbers and isolation seem to be necessary for the establishment of new types. These conditions changed greatly after the introduction of agriculture and disappeared with the

[2] See Keith (1915 and 1931) for descriptions of these fossils. Hooton (1931) gives useful short accounts of fossil men, and the new edition of *Up from the Ape*, now being prepared, will include all the important recent discoveries.

fabulous increase in population which followed the Industrial Revolution.

At present the characters of world population are being determined largely by mixture and differential birth rates. It is hard to see how new racial types can form under present conditions. It should be noted that the later phases of human evolution introduced new factors. While the earlier phases of man's biological progress can be treated just like those of any mammal, the later demand a knowledge of social factors. It is for this reason that social and biological scientists must cooperate in the study of man.

Granting that there was a dispersal of a rugged, generalized, modern man, from what type of man was he derived? There is no question upon which there is less agreement among students of human evolution. Some maintain that the modern type is of great antiquity (Galley Hill, Swanscombe skulls lend support to this view). Others feel that modern man is recent. The prevalence of other more primitive types until the latter part of the Ice Age, and the sudden spread of modern man at that time corroborates this hypothesis (to which the writer leans). However, there seems little doubt that the earlier Neanderthal men (Galilee, Ehringsdorf, Skhul 5, Steinheim; see Weidenreich, 1943), and the Sinanthropus and Pithecanthropus types are ideal morphological ancestors for modern man.

These ancient men differ markedly from modern man. They have much larger and more massive faces, lower foreheads, smaller average cranial capacity, and their limbs show characteristic differences. Whereas the early Homo sapiens fossils, if alive today, probably could pass unnoticed in the New York subway, one of these ancient men would draw the attention of everyone. They were quite beyond the range of variation of modern man. However, they were true men. They had large brains (compared to those of apes), human faces and teeth, and human limb bones. They walked upright as we do, and in their morphology are infinitely closer to modern man than they are to any ape.

Ancient man spread out, just as early modern man did. His remains have been found in Europe, Russia, China, Java, Palestine, and Africa. Apparently, ancient man never reached the New World or Australia.

To which of the living races are these ancient fossils particularly closely related? To none. The major races gained their individuality long after the time when the earliest representatives of modern man lived. Before these earliest modern men there is a morphological gap, perhaps bridged by a skeleton from Palestine.

If any of the modern races is particularly primitive, its remains should be found in early strata and should be proportionately more numerous in more ancient deposits. The only one of the modern races of which this would be at all true is the aboriginal Australian. The Wadjak, Cohuna, Talgai series of fossils seems to offer connecting links between early modern man and the Australian. Also of living men the Australian seems to have more in common with generalized early Homo sapiens, although the living Australians have evolved along lines of their own. They simply seem to have changed less than the others. Even the aboriginal Australian is definitely a modern man and lacks the peculiarities of the face and limb bone which characterize ancient man.

Since the existing races have a common ancestor in early modern man and since racial differences cannot be traced back even as far as ancient man, what possible purpose is there in comparing living races directly to the apes? Let us see how long a history of common ancestry the living races have compared to the time they have been separate. Most students of human evolution feel that man must have had an independent course of evolution since at least the end of Miocene times. Many (Clark, Gregory, Hooton, Keith, Osborn,

Wood-Jones) would add millions of years to this. Early modern man lived from twenty-five to fifty thousand years ago (considering the Pliocene period to have lasted six million years, the Pleistocene one million, and Recent twenty-five thousand). Let us be generous and say that the races were distinct for fifty thousand years, although all known skeletons of definite racial affiliation are not over twenty-five thousand years old. Taking a minimum for the length of time that man has been separate from the apes, and a maximum for that during which the races have been distinct, the time during which all living people have shared a common human ancestry is a hundred and forty times that during which any race has been independent. To put the matter conservatively, every living race has had at least one hundred times as much of its human ancestry in common with all the other races as it has had alone. Since what divergence has taken place is all after the attainment of essentially modern morphology, it is hard to see how any of the living races can be considered significantly more primitive than the others. None of them is close to ancient man, let alone the apes. All are very modern products of the slow process of evolution.

The genealogical tree which appears in many textbooks is completely misleading. In this tree the races appear to have been separate for a very long period of time, for most of the Pleistocene period. In fact separate races are indicated as old as any definitely dated skeleton of man. Then, too, the time scale is completely misleading. The Pleistocene is indicated as longer than the Pliocene and the Pliocene than the Miocene. Omitting time or using a changing time scale is very confusing, and is such a frequent feature of genealogical trees that it deserves special mention. Only one of eight trees which I have before me keeps the time scale even approximately correct. The effect of seeing such a tree is that the student gets the impression that the races have been separate for approximately one-third of human history. If this were true, there would undoubtedly be great differences between them. One should never use a chart on which the scale changes or is omitted, because the student inevitably gets the wrong idea. It is impossible to put both the divergence of the human line from the ape and the differentiation into modern races on any single chart. If the time from the divergence of human and ape stems to the present be represented by an ordinary pack of fifty-two playing cards placed end to end, all racial differentiation would be on less than half of the last card. This is one of the most important facts of human evolution, and the use of genealogical trees with changing time scales, on which the importance of all late events is exaggerated, has obscured it almost completely.

The practice of comparing *individual* races directly to the apes should be abandoned. It is usually done with the best intent to show that, although the White is more like the ape in one character, the Negro is in another. But what this practice actually does is to keep alive the idea that it is reasonable and scientifically defensible to compare living men with living apes for the purpose of arranging races in some hierarchical order. What meaning have these comparisons when the races have nearly all their ancestry in common?

Unless it could be proved that the living races differed greatly in their relations to ancient man, it is pure waste of time to compare them individually to the apes to determine which is the most primitive. It is sound biological practice to compare closely related animals first. In order to determine the relation of a Shetland pony to a Shire horse, no one would compare each to Eohippus. It is reasonable to compare living men to apes to determine how great is the anatomical divergence between mankind as a whole and apes. Similarly, a modern horse might be compared to Eohippus to see how great a change there

had been in horses since Eocene times.

Different characters are appropriate when discussing different stages in man's evolution. Since racial differences are small and recent, they are of no use in discussing remote phases of human evolution. Misunderstanding of this point has caused so much confusion that it is worth giving two illustrations. Long-headedness is often spoken of as being a primitive character. Since some gorillas, particularly from the Cameroons (Randall, 1943), are round-headed, it has been argued that long-headedness is not primitive. Now early modern man was long-headed, and the round-heads, which appear later in the fossil record, seem to have been derived from the early long-heads. A character which changes so rapidly is of no use for comparisons with gorillas Note that the word "primitive" changes its meaning constantly. One speaks of primitive characters meaning those of (1) early modern man, (2) ancient man, or (3) apes, and in each case the characters are different. How vitally a little knowledge on this point is needed is well illustrated by a pamphlet which was published recently. The authors wished to prove the unity of the human race. One of the two illustrations which they picked was the number of teeth. The human dental formula is the same as that of the apes and Old World monkeys. The other illustration (the number of bones and muscles of the foot) is equally irrelevant. The unity of the living races is proved by the anatomy of *modern man,* not by characters which are shared with hundreds of nonhuman primates and had their origin at least as far back as the basal Oligocene.

If the fossil record showed that the groups which are now recognized as races had been separate as early as the Oligocene period, then the dental formula would be a relevant consideration. The interpretation of the fossil record is the crux of all thinking concerning the antiquity of race.

In summary, the most direct and important evidence there is on the antiquity and relations of races comes from the fossil record. This evidence is being augmented constantly by new finds. Therefore we are sure that the continued study of fossil man will give clearer insight into this problem.

THINKING ABOUT RACIAL PROBLEMS

Up to this point I have tried to present a view of racial classifications which stresses ends and methods, and have tried to interpret the fossil record to give a perspective on the antiquity of races. Naturally, in a short paper it is impossible to do more than indicate a point of view.

I do not believe that an understanding of the anatomy of race will settle the social problem of racial discrimination. I agree entirely with Benedict (1940) that this is only one part of the more general problem of social discrimination. Nevertheless, if racial classifications are to be discussed at all, it is necessary to try to *understand them first,* and then to evaluate. Making serious errors is the price which one pays for discussing race, without trying to understand the anatomical situation. One can imagine Nazi biologists laughing with delight if pamphlets containing misstatements are translated and sent to Germany after the war. There is no easier way to discredit a whole point of view which one does not like, than finding one or two glaring errors. Therefore, if we are to discuss racial matters with the Nazis, we had better be right.

The following section of this paper is devoted to the analysis of a series of problems which have risen repeatedly in recent discussions about race. In each section my aim will be to try to clarify thinking, not to supply final answers.

HEAD FORM AS AN INDICATOR OF RACE

It has been said recently that the form of the head (cephalic index) is useless as an indicator of race. This is claimed because both broad- and long-heads appear

in Negroes, Mongolians, and Whites. Now instead of taking an absolutist point of view, let us consider the history of Europe for a moment. The early men were long-headed. The migrations of round-headed people came from the east. Some of these migrations are historically documented and recently Candela (1942) has shown how certain ones explain the distribution of blood-group B in Europe. The shape of the head is one, and only one, of the anatomical features in which these migrants differed from the earlier peoples. In considering the changes which have taken place in the population of Europe, the cephalic index is useful. From the pragmatic point of view, it is quite irrelevant whether the index is useful in any other problem. We are not trying to prove whether the cephalic index is good or bad in an absolute sense, but are merely asking whether this index aids in unravelling a small part of the complex history of Europe.

There is nothing magical about the shape of the head. Sometimes, along with other characters, it is useful in racial classification. The point which should be stressed is that head form is not good or bad in an absolute sense, but useful, or not useful, in a particular situation. Without knowing the situation, one can not judge.

The pragmatic point of view is essential both in judging single characters and whole classifications. For example, it has been said that racial classifications mean very little because the races intergrade so that all people cannot be classified. From the practical point of view, the question is whether enough people can be easily classified so that racial classification is useful.

GENETICS, PHENOTYPICAL AND GENOTYPICAL CLASSIFICATIONS

Geneticists and others have suggested that the classification of man should be based on the primary units, the genes. The classifications we have now are based almost entirely on phenotypes, that is, adult structure.

It should be remembered that, as mentioned previously, the classification of adults is now useful to anatomists and many other people. The obstetrician cannot wait until the genetics of pelvic type is known before making a delivery.

Since at the present time there is no genetic classification of man, the main question seems to be whether future knowledge of gene-frequency distributions will substantiate present classifications. My belief is that it will, as far as the major groups are concerned, but that sub-races which do not breed true and are found only in mixed populations will never be reconciled with genetic theory. The blood groups are the only traits whose mode of inheritance is known and which have been studied extensively in many parts of the world. The distribution of the blood groups shows marked regional differences. For example, group O is very frequent among American Indians, and group B among the Chinese. That the same genes are present in all races but in different frequencies seems probable. Only the future will tell, and the sooner the genetic information is available, the better for all.

THE MEANING OF THE WORDS "RACE" AND "SPECIES"

Some writers have tried to settle racial problems by substituting another word or words. This represents the opposite pole from that stressed in this paper. We have already seen that "primitive" may have a variety of meanings. After all, words are only symbols, and it is ends and methods which are the framework of science. If people want to use other words instead of "race," of course they have a right to do so. The danger is that changing words may appear to solve problems, when it only obscures the fact that we are doing the same things as before. The word "race" has as many different meanings as there are methods used to sort races.

Some groupings are based on much knowledge and some on very little. Some are undoubtedly nonsense from any point of view. Vocabulary can be multiplied prodigiously to try to reflect each change in method, or we can simply say that the meaning of the word in any given case, depends on the operations performed in the creation of that race. The operational point of view (Bridgman, 1936) keeps one's attention constantly on knowledge and methods, and off distinctions that have only a verbal basis.

The importance of emphasizing operations actually performed is well shown by the word "species." It has been stated recently that all living men belong to one species because all the races can interbreed. Now at least as early as 1863 (Zuckerman, 1933) it was known that groups of monkeys classed in different genera would interbreed. If one pauses to think that the primates have been classified in museums and anatomical laboratories, it is obvious that tests of fertility cannot have been one of the operations actually performed. The species of primates are natural groups which are distinct, that is, every individual can be classified as belonging to one. Species are the smallest natural groups about which this is true, because, since subspecies (races, varieties) intergrade, many individuals fit equally well in more than one group.

Existing races of man are called "races" and not "species" because their characteristics intergrade. If there were no intergrades between Bushmen and Europeans and if they were classified in some museum using the same methods used for monkeys, they would be put in separate species. As the classificatory system is now used, lack of intergradation, and not inability to breed, is the characteristic actually used. The history of how the idea of interspecific infertility arose is worth considering because it shows the necessity for the operational point of view. Species of monkeys were seen living in the same locality and no hybrids were found. Since it was assumed that any monkey would mate with any other (which is not true), the fact that no hybrids were found proved that species were not able to interbreed. Therefore species were thought to be mutually infertile groups. So a conclusion, which is now known to be false, became a criterion of a group which actually was defined entirely differently. If species had been defined in terms of what people *did* in separating them, inability to cross would never have been considered a specific character for primates.

METHODS OF CLASSIFICATION AND PURE RACES

All races of man are mixed, and within any racial group there are always individual variations. After all, even monkeys of the same subspecies collected in the same locality vary considerably (Schultz, 1926, 1937; Washburn, 1942), so there is no reason to expect greater homogeneity in man. In the primates as a whole, there appear to be no pure races in the sense of types, such as some strains of laboratory rats or mice, which are held constant by inbreeding and removal of any deviating individuals. The human situation is more complex than that of other primates because human wanderings and migrations have been so much more extensive. Also human social habits, such as trade, war, and slavery, introduce an entirely new set of factors.

Mixing has played a much greater part in the physical history of man than it has in the evolution of nonhuman primates. In this sense it is correct to say that there are no pure human races.

However, the word "pure" has been applied to races created by two different methods, and it is very important to keep these methods separate in one's thinking. For example, let us consider the construction of the races frequently called "pure" aboriginal Australian and "pure" Nordic.

In the case of the Australian aboriginal, "pure Australian" means the Australian black as he is observed to be, without obvious mixture with other races. The characteristics of the type are derived from the study of the population. The range of variation in each character is charted. The children belong to the same group as their parents, that is, the race breeds true within the limits of the parental population.

"Pure Nordic" means a group of people who are tall, long-headed, blond, blue-eyed, and who have the numerous other traits which are attributed to this race. Do Nordics breed true, that is, will the children of Nordic parents be Nordic? The children may be too short, too round-headed, too dark-haired or dark-eyed to be classed as Nordics. From this it is clear that the group which has been selected as pure Nordic is pure in phenotype only. How was the Nordic race created? Individuals were seen with the characteristics attributed to the race, and then the pure race was postulated, and the observed situation described as the result of mixture. In the case of Nordic the meaning of "pure" lies in the operations performed to construct the race, that is, in the creation of an *imaginary type* which is not found. In the case of the aboriginal Australian, "pure" means a population which exists, which is studied directly, and which is without obvious admixture. This does not mean that there never was any crossing, but simply that our methods can not detect any.

The descriptions of some races, such as the Australian, are based on the study of populations. Other races, such as the Nordic, are created by selecting individuals from a population and then describing the selected group.

The great interest in racial purity has taken attention from the fact that some of the mixed races cannot even be demonstrated as actual groups of living, breeding human beings. Each race is worth no more consideration than the operations which created it. Whether we call the Australian race "mixed" or "pure," the *same operations* are used to create our description. Whether the Nordic race is called "mixed" or "pure," it is still an arbitrarily limited creation of the imagination. Only when one studies how races are created and in what situations these concepts are useful, does the vast difference between Australian and Nordic become apparent. The crucial point is, not that the Nordic race is mixed, but that there is no evidence that there ever was a group of human beings who had the characters of Nordics, and who passed these traits along to their children.

The first step in racial analysis is to find out whether there is a self-perpetuating group of human beings who actually have the characters of the race. The second is to see what methods were used to describe and delimit the race.

It is only by knowing how particular races are described that one can decide which ones are useful categories and which are useless. Below is an analysis of one race.

Race:	Pure Nordic
Location:	Nowhere
Method:	Imagination
Result:	Nonsense

SUMMARY AND CONCLUSIONS

The conclusions of this paper may be briefly summarized as follows:

1. Racial classification is an anatomical concept and is useful for anatomical purposes.
2. The fossil record shows that the living races are extremely modern from a biological point of view, having had most of their human ancestry in common.
3. Keeping purpose and method constantly in mind removes much of the confusion which exists in current thought about race.
4. To understand race, a knowledge of human biology is necessary. Be-

cause words are only symbols, a knowledge of the things symbolized is imperative for proper understanding. It is here that the science teacher has a great contribution to make in both fact and method.

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TROPICAL DISEASES IN NEW ENGLAND [1]

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SINCE December 7, 1941, all of the Americas have become conscious of war—global war extending to all the continents of the world. On that fatal day, Japan suddenly burst America's bubble of isolationism. Yes, many of our citizens had believed that the United States was self-sufficient and apart from the rest of the world, safe from the conflagration which was charring the rest of the world. Public Health (1)* and military officials, however, have been deeply concerned for many years, fearful of the extension of the plague of war to our continents. Although war is often limited by political boundaries, disease recognizes no such limitations. Bacteria do not recognize any laws and are equally dangerous to friend and foe.

WAR AND DISEASE

Since time immemorial (2), wars have been attended by pestilence and disease. Through all history, famine and disease are constant companions of war. Pestilence and war are old tried companions; their goal is death and destruction. On many occasions, disease, rather than military operations, determined the outcome of campaigns and the course of history. Nations have been defeated by war-brought pestilence. On many occasions, armies were, in fact, traveling reservoirs of infection spreading both endemic and epidemic diseases throughout the civilian populations with which they have come into contact. The resulting outbreaks, however, have been restricted to the zones of military operations and only rarely followed the soldier on his return home from distant war fields.

The history of wars prior to the twentieth century is characterized by accounts of great epidemics of typhus fever, smallpox, typhoid fever, dysentery, malaria, cholera, and bubonic plague. In twentieth-century warfare, influenza, meningococcal meningitis and other respiratory diseases, and arthropodal- (or insect-) borne diseases, are the chief concern of military and civilian health authorities. Under war conditions, many of the safeguards of the health of both military and civilian populations are abandoned. Large numbers of people are crowded into concentration camps, bombshelters, and military establishments, where the effort to keep warm, the primitive environmental sanitation, and the lack of personal hygiene are all conducive to the spread of infectious diseases. The concentration and movement of armies and refugees, accompanied by the hardships of exposure and fatigue, general malnutrition, and the lack of proper medical care provide the fuses for the explosion of widespread epidemics.

More soldiers have been killed by infectious disease than by bullets in all wars prior to the Franco-Prussian War of 1870, when the German Army experienced more deaths from battle than from disease. During the Russo-Japanese War of 1904 both sides suffered more from war casualties than from disease. In spite of the toll of influenza, the AEF of 1917–18 (3) reported fewer deaths from sickness than from battle, although for the entire United States Army, at home and abroad, the

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* See Bibliography at end of article.

deaths from disease were more numerous than battle casualties. During and after World War I all infectious diseases except the common childhood communicable diseases were highly prevalent in eastern Europe. There was an epidemic of typhus fever and relapsing fever throughout Russia, Poland, and Serbia. Fortunately, these diseases did not spread into western Europe and to regions where our army was fighting. Overshadowing all other outbreaks was the influenza pandemic, which caused an increased mortality from pneumonia. Meningococcal meningitis was epidemic, while dysentery, smallpox, tuberculosis, and venereal disease increased in prevalence. Malaria was victor in Macedonia (4) and decimated the opposing armies to a tragic ineffective fraction. Although it had previously disappeared from most of Europe, malaria returned with the soldiers to central, eastern, and northern Europe to ravage the civilian population for over a decade. The United States, fortunately, escaped the importation of all the exotic diseases which were stirred up in that conflict. Since our armies did not fight in areas where these diseases were prevalent, they did not succumb to them, nor did they bring them back to this country on their return.

This global war is much more hazardous to civilian health than any in history (5). The civilian population is being exposed to the potential hazards of disease throughout the fighting zones and in those areas to which the troops are moved. This risk of infection will probably not reach its peak during the actual warfare, but rather in the period of population readjustment following the cessation of hostilities. With battles raging in all parts of the globe and principally in the tropics and subtropics, new hazards face our fighting men.

Large numbers of non-immune susceptible individuals are being concentrated in areas where so-called tropical diseases (6) are prevalent. Under battle conditions, they are being exposed to the added risk of the limitation of known effective control measures, unavoidable in the face of combat. To the classic list of military diseases such as dysentery, typhoid, paratyphoid, typhus and malaria, the military personnel have now the added risk of an entire galaxy of tropical disease. The problem presented by latent unrecognized infection and the carrier state among our fighting personnel cannot be fully appreciated. The similar problem presented by refugees in mass emigration from war-devastated areas cannot be anticipated. The danger to the civilian population in the United States does not arise from the recognized and treated cases but from these latent infections, carriers, and refugees, who may bring the infection back to their homes.

TROPICAL DISEASES

For many years, tropical diseases were considered to be indigenous only to tropical and subtropical areas. But today it is known that the term "tropical" must be interpreted to indicate the usual abode of these diseases, but by no means their geographical limitations. Yellow fever, for example, has been epidemic in most of the ports along the Atlantic Seaboard as far north as Boston and New Bedford. Fortunately, these outbreaks were limited to the summer and died out with the onset of cold weather.

Tropical diseases are more prevalent in the warmer regions, many of them are caused by protozoan or metazoan parasites, many require particular intermediate hosts or special arthropodal vectors. Some of these diseases are limited by special factors such as climate, distribution of the intermediate hosts, availability of the arthropodal vector or carrier, etc. Most of these limited tropical diseases are of little or no danger to the United States with the exception of malaria. Other tropical diseases, which are spread by the lack of proper sanitation and personal hygiene,

tend to have world-wide distribution and these are of more serious danger to the civilian population of the United States, as bacillary and amebic dysentery.

A tropical disease may gain entrance into areas where it has not been prevalent by one of several methods:

1) Disease may be introduced by carriers or by some cases which may not be recognized. The chances of this type of entrance are greater than ever because of the development of radar and the relative safety of both military and civilian aviation. It is entirely possible for a traveler to leave India and arrive at a Boston airport perfectly well but later develop bubonic plague or yellow fever which he contracted in India.

2) Animal reservoirs may be introduced from areas where the disease was indigenous and thereby bring the disease with them. This is thought to have been the means whereby equine encephalomyelitis was introduced into New England in 1938.

3) Insect vectors may be brought by airplanes, ships, or other means of transportation. Yellow fever was brought into Boston by clipper ship; Aedes aegypti mosquitoes bred on shipboard in open casks of fresh water. The recent outbreak of malaria in Brazil (*7*) was due to the importation of Anopheles gambia from Africa.

4) The disease may find new hosts in the new area. Examples of diseases which can adapt themselves to a variety of animal hosts are bubonic plague and brucellosis or undulant fever. The latter was introduced into North America, probably in Texas, and although originally a disease of goats is now highly prevalent among cattle, even in New England.

5) The disease may find a new insect vector in the area invaded. The transmission of yellow fever in different areas is an illustration of the adaptability of various insects to the spread of this disease. Nine species of Aedes mosquitoes and some of the members of the genera Eretmapodites, Culex, Mansonia, and Anopheles have been shown to transmit the virus of yellow fever in West Africa.

6) New or different strains of the disease may be introduced into an area where less virulent strains were formerly prevalent. This is illustrated by the introduction of tertian malaria (Plasmodium falciparum) into areas where benign malaria (Plasmodium vivax) was formerly prevalent. As little or no cross immunity exists between these two types of malaria, the more virulent type will cause a widespread outbreak with many resultant deaths.

THE OUTLOOK FOR NEW ENGLAND

Naturally, here in New England, health authorities are not so much concerned with the possibilities of tropical disease among the civilian populations of Europe, Asia, and Africa as with the possibility of their importation into the New England States. On this point, one can feel rather reassured, it is extremely unlikely that any of the tropical diseases will become indigenous in New England. In fact, New England is relatively safe from most of the tropical infections, and even if latent infections and carriers return to local communities there will be only rare cases, if any, of these exotic infections.

Some of these so-called tropical diseases are endemic now in New England and, although additional carriers may bring their infections into local communities, few additional cases will result as long as proper sanitation and personal hygiene are maintained. This fact is especially applicable to the enteric diseases (8), such as typhoid, paratyphoid, bacillary and amebic dysentery. So long as excreta are properly disposed of, and so long as carriers of these organisms wash their hands thoroughly after going to the toilet and before handling food, there is no danger of an outbreak.

Typhus fever, relapsing fever, and other

louse-borne (9) diseases are another group of tropical infections which are not likely to find a foothold in New England. There was a time when some of the immigrants did not consider themselves to be virile unless they were lousy—infected with lice. At present, however, body lice are a rare finding in Massachusetts. With adequate use of hot water and soap—the American traditional Saturday night bath—the public can remain free of lice and thereby prevent the spread of these diseases. If the rat population were immensely increased, by enemy destruction of cities, and if municipal sanitation standards were broken down, then there might be danger of an outbreak if lice and the infecting organisms were introduced. Under a similar breakdown of sanitation, outbreaks of cholera would be possible. However, since there are good reasons to believe that enemy massive destruction is unlikely and since the possibility of introducing these infective agents is remote, there need not be concern about such diseases as typhus fever, relapsing fever, bubonic plague, and cholera.

Dengue and yellow fever (10) are two other diseases which are unlikely to be prevalent in Massachusetts, as the mosquito vector and the infecting organism must be imported. Moreover, the Aedes aegypti mosquito, the vector of these infections, cannot survive New England winters. Under most unusual conditions, therefore, it is possible, although highly improbable, that these two diseases may gain temporary access. Such outbreaks would naturally disappear spontaneously with the onset of cold weather and would not reappear again unless reintroduced.

Perhaps the disease which may cause most civilian concern in the United States is malaria (11). Malaria has been endemic in New England and there have been at least three epidemic waves, two of which spread up the rivers from Long Island to Connecticut and Massachusetts. During the first decade of the twentieth century the disease was endemic in the valleys of the Charles, Blackstone, and Sudbury rivers, but for almost 20 years only rare cases have been reported. During the past 14 years there have been only 11 reported cases of malaria in persons who were never out of Massachusetts and who apparently acquired the disease as a result of mosquito bites. Fortunately, climatic conditions and land improvements have been unfavorable to the continued existence of malaria in New England. With the building of each house and the cultivation of each new farm, additional mosquito-breeding places are destroyed. At present, health authorities are convinced that the concentration of Anopheles quadrimaculatus, the carrier in this region, is not sufficient to maintain malaria at an epidemic level. However, if carriers of malaria return, they may act as foci of small local family or neighborhood outbreaks. Adequate treatment of all cases and proper screening of houses are, however, excellent control measures. Both the Army and Navy are treating all cases, and any soldier or sailor who is discharged with malaria or who enters an Army hospital in the state is carefully followed up by the Massachusetts Department of Public Health. All measures are taken to protect the public. Entomological surveys are made of the environs of each military establishment where malaria patients are likely to be hospitalized. And the United States Public Health Service, working in cooperation with the United States Army and Navy, and with the Massachusetts Department of Public Health, is ready to undertake mosquito control measures, should the need arise.

SUMMARY

In summary, Public Health authorities expect that throughout the world there will be a dissemination and an increase in tropical diseases. American soldiers and the civilians in the war areas will contract the diseases. Returning military and naval

personnel and civilian refugees may import the infection to areas previously free of these diseases. Latent infection and the carrier state are the two most likely means whereby infection may be transmitted. Some tropical diseases may gain a hold in certain parts of the United States if—

Introduced by cases, or carriers.
Animal reservoirs bring the infection.
Insect vectors are introduced.
The disease finds new hosts.
The disease finds a new vector.
New or different strains of the disease are brought.

New England, however, is relatively safe from tropical diseases. There may be an increase in some enteric diseases which are already prevalent here, such as typhoid, paratyphoid, bacillary and amebic dysentery. Adequate sanitation and personal hygiene in washing the hands after going to the toilet and before handling food should prevent these cases. There may be local, limited outbreaks of malaria but these outbreaks, if they occur, will be very small and short-lived, and can be controlled by adequate treatment, screening of houses, and, if indicated, mosquito-control measures.

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CONSERVATION: FOCUS OR INCIDENT IN SCIENCE EDUCATION?

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IN 1728 Colonel William Byrd II, in surveying the Dan River Valley of Virginia reported: "The soil we passed over this day was very good. Charming valleys bring forth like the land of Egypt. Grass grows as high as a man on horseback and the rivers roll down their water to the sea as clear as crystal. Happy will be the people destined for so wholesome a situation, where they may live to the fullness of their days with much content and gaiety of heart."

A short half century later man had ravaged the soil to such an extent that Patrick Henry was moved to state before the assembly of this same Virginia: "Since the achievement of our independence, he is the greatest patriot who stops the most gullies." Patriots there were. But there was so little informed intelligence on the matter that today, according to the United States Soil Conservation Service, fully 50 percent of the million and a half acres of arable land in this once rich and prosperous valley has been completely or almost completely destroyed by the insidious processes of erosion.

There is no need to stress the fact that soil erosion is a national problem of great urgency. In 1937 state and federal experts appraised the agricultural land of the United States and reported that 61 percent—about 253 million acres—was subject to continued erosion or was of such poor quality that it did not provide a satisfactory income to farmers (assuming price levels for farm products of the period 1921–1936). It was the considered opinion of this group of scientists that to continue present farming practices on this land was to "mine" it and, progressively, to bring about its destruction.

Note that this leaves only 39 percent of our present farmland that can safely be cultivated with traditional farming practices. Add to this 39 percent the land which is not now under cultivation but which could be farmed, and the total arable land that could safely be cultivated under present farming practices is *a little less than half of the present cropland area.*

What would happen if the best known practices of agriculture were put into effect? Suppose we were to adapt our methods of agriculture to the land, using our available experts and applying our present knowledge to each farming situation. According to the Soil Conservation Service fully 82 percent of our present croplands could then be safely cultivated and could yield a satisfactory return to the farmer. If there were added to this acreage the lands which are not now farmed but which could be safely cultivated under best farming practices, we would have slightly more arable land than our total present cropland.

Now where does the science teacher come into this picture? What is his responsibility? I have suggested the gross aspects of a single serious conservation problem facing American people today. There are many other urgent problems of conserving—of using wisely—our resources, biological, mineral, and above all, human. Instead of describing them, I shall attempt to analyze and support a trend in science teaching that is, I believe, highly significant. I propose to present a viewpoint, through this analysis and support, which may throw light on the science teacher's responsibility and function in regard to such major problems as that of conservation. But first allow me to make

certain assumptions in regard to science and science education that may clarify the philosophy basic to this trend and viewpoint.

The value of science lies in the fact that, through its pragmatism, man gains a measure of ability to predict and control in pursuits in which he wishes to, or must, engage. The pragmatism of science enables man to know beforehand the results of experiences and activities that he contemplates. An experiment, as such, may or may not be of value. Certainly if it is never applied to situations in which conflicts or problems still exist it is of dubious value. In other words, experimentalism becomes of value to the extent that extrapolations and generalizations are adduced and applied to predict and control in such a fashion that desirable outcomes are attained.

But in a democracy the predictive value of scientific research may be lost unless supported by the forces of education. In a democracy, application of the fruits of scientific research is predicated upon the dissemination of the truths so determined. Note, for example, that we have at the present time sufficient experimental data to enable us to conserve our soil resources, but that through default of educational treatment we have not used, and are not using, those data to any great extent. In a dictatorship it may be sufficient for a "select" group to possess predictive and controlling knowledge, for in a dictatorship such a group commands the power to apply that knowledge in whatever fashion it sees fit. We know all too well the misdirection that power may take. And we know all too well the ultimate frustration of science itself in such "select" hands. It is imperative that democratic peoples solve their personal, local, regional, and national problems in terms of the objective data that only science can provide. Moreover, it is imperative that our people, through education, learn to solve these problems democratically. Herein lies the supreme challenge to American educators and certainly no less to that particular group trained in the methods and content of science. So long as we avoid these existent and urgent problems; so long as we address our competence and energy to the contemplation of sterile subject-matter, that long are we ignoring a major responsibility to young people and society today.

If these assumptions are sound, and recent evidence secured by the National Committee on Science Teaching discloses that a great majority of the nation's science teachers believe them to be sound,[1] it is our task to discover increasingly valid methods of actualizing our goals. What general methods of organizing and building science curricula are being employed at the present time, and how successful are these methods in achieving adequate treatment of personal and social problems—that of conservation, for example?

Three methods are employed in building curricula in science education. One is that of surveying the entire field of the particular science to be considered, selecting as judiciously as possible from here and there to build a so-called logical organization of subject matter. Let us call this the *field-covering* approach. This method is, of course, the traditional, and still most widely used method of building science curricula. Its *raison d'être* at the present time seems to be primarily inertia. Science entered the curriculum of the lower schools in the latter part of the eighteenth century partly to satisfy the growing demand for basic education to prepare youth for further science training in the colleges of the land. This was considered highly desirable so that students could advance, through research, the fields of science which had given great promise, according to the optimistic views of the day, of solving the ancient ills of the world. Hence the science curricu-

[1] Burnett, R. W. *Opinions of Science Teachers on Some Socially Significant Issues: A Survey of Teacher Opinion and Its Implications for Teacher Education.* New York, 1941.

lum was designed as a fundamental training for the producers of the science which was so badly needed.

Of course we need today, as much as then, to prepare young people for leadership in scientific pursuits. But today the colleges have largely taken over the task of providing fundamental training in restricted science fields, and awareness is growing that the *field-covering* approach in secondary school teaching is neither the best approach for preparing producers of science nor for meeting the broader needs of this producer group and the far larger group of young people who will be consumer-participants in the world to come. It is increasingly believed that the best fundamental education for research specialists and laymen alike is that which gives promise of interpreting the significant problems of today and providing alert and critically informed intelligence upon these problems. The question is not whether to teach "fundamentals," but rather what information, attitudes, and skills *are* fundamental for optimum living in America today.

A second approach in the selection of science content and organization grew out of the increased realization that the *field-covering* approach was generally sterile in meeting the needs and interests of young people and society today. A committee was organized in 1930 to "assemble and interpret material showing the trends in the teaching of science, and to formulate recommendations for work." I speak, of course, of the committee which published its report early in 1932 as the *Thirty-First Yearbook of the National Society for the Study of Education.* This report suggested selecting broad generalizations and concepts and organizing the science work around them. Let us call this the *generalizations approach.* These broad generalizations were those that were, or had been, influential in shaping the thinking and action of men for better living. But in application, teachers too often forgot the manner by which these generalizations had been developed through inductive scientific investigation, and failed to recognize that potentially significant generalizations might be sterile of application unless taught in a framework of developing problems real and important to the learner. Consequently there was, all too often, a treatment of generalizations as things to be learned, as dicta from authorities, rather than as logical outgrowths of rich, meaningful, and developing experiences. Ability to deliver verbal evidences that the generalizations had been learned was too often the only evidence that these potentially valuable generalizations had altered the thinking and action of the learners. Under these conditions, the *generalizations* approach became virtually indistinguishable from the *field-covering* approach.

Nonetheless, the *generalizations* approach was a long step toward the development of meaningful science curricula. It led directly to the establishment of a third criterion for the selection of science content. This criterion, which is gaining increased acceptance at the present time, is found directly in the problems with which individuals must, or choose to, deal in living in present-day America. There are, it seems, two large advantages that this criterion has over the other two approaches ordinarily employed. The first is logical, the second psychological.

The logic of this criterion lies in evidence that organization of content in terms of "covering the field" is an indirection that ultimately *actually does* find its criteria in the problems and situations with which people deal. Although we should line the walls of a library with the archives of science, the job of gathering scientific data would hardly be begun. Naturally a selection must be made for educational purposes. That selection must be based upon certain criteria outside of the science data as such. And that is precisely what has been done. Selection in the past was made, however, largely upon the basis of those

areas deemed fundamental for furthering research in the disciplines of science, and of certain other areas that were at one time actually fundamental for meeting successfully the problems of that time. Clearly, many of these so-called fundamentals were and still are actually basic to the understanding of matters of everyday importance. But it is equally clear that the *determination of what actually is presently fundamental* can be found only by first searching the existent situations and problems that American people face and then returning to the archives of science for materials and organization suitable for clarification of these problems.

The psychological advantage of selecting science content and organization in terms of present, nonacademic problems lies in the fact that such problems, because they are real, are accepted as such by the learner. This may mean the difference between real learning and meaningless verbalized acceptance of concepts the teacher holds important. Nonsense syllables are not easily learned, and if learned, are verbalizations. Unless the learner appreciates the relevance of what he is studying to problems that he personally accepts as real, he is, in effect, studying nonsense syllables.

The real distinction between these three types of content and organization is clearly evident when we observe actual teaching situations. In most instances the observable difference is that in one case the problems become *incidents* of instruction and in the other the problems become *focal points* of attack. All three methods may eventually cover much common material. However, in the *field-covering* approach the material is organized around an inherent logical system that may or may not appear logical—that is, meaningful—to students. In the *problem* approach, on the contrary, the student, like the scientist, becomes aware of a problem worthy of his attention; clarifies the problem for attack; searches out significant and relevant data through observation, readings, and experimentation; and ultimately arrives at conclusions, and from these at generalizations, based upon and necessarily growing out of the data he has developed. It is unnecessary to dwell on the value of this method for attaining those pervasive but elusive objectives most science teachers subscribe to: the development of that group of skills, abilities, and dispositions which we term collectively the scientific method and attitude, and the development of democratic skills and appreciations.

Now let us address directly the problem of conservation education and examine the differences that are apparent in teaching based upon selection and organization of content through the *field-covering* approach on the one hand, and the focal *problem approach* on the other. We may narrow the field of conservation to one area, that of good land use.

An analysis of extant biology books discloses a strong allegiance to content selection and organization on a *field-covering* basis. True, those books which have appeared in the last few years have given increased attention to conservation, but the reviewer gains the inescapable feeling (which is probably shared by high school students as well) that the emphasis is on plant and animal functions, adaptations, and so forth, and that somewhere along—often without apparent meaningful relation to the main emphasis of the text—appears a tidy section on conservation. A real understanding of good land use is probably predicated upon certain understandings of soil, water, plant life, animal life, and the ecological relations among these. Yet many textbooks have followed the formula of presenting data on plant and animal life separately and near the front of the book and introducing a section on conservation in a part of the book that presumably will be studied much later in the course.

The teacher, using such books and accepting thereby the *field-covering* approach, generally finds such an organization con-

ducive to the task at hand, which is to provide as meaningful as possible a coverage of the field. Many teachers, using this approach, supplement the textual material with conservation pamphlets and activities designed to provide more adequate treatment of this important area. But observation and analysis force the conclusion that this general organization necessarily places conservation and other major problems as incidents, or at most as coordinate parts, of a none too well integrated series of discrete learning experiences.

I have not dwelt long on an examination of procedure in teaching the problems of good land use according to a *field-covering* organization because most of us are quite familiar with that organization and appreciate the extent to which conservation is considered. What differences appear when the content and organization are based upon major problems such as conservation which are considered as foci of attack?

There are many examples of this type of work. Let me describe just one biology class in which the organization for the major portion of the work was around a limited number of really significant problems amenable to treatment through biological information and scientific skills. The problems of good land use constituted one of these problem areas. There were no precisely pre-determined time limits in which this material was to be covered. The problem was opened by a discussion of the national picture in which a variety of references were used, the chief source being publications of the Soil Conservation Service and of the Forestry Service, and state and regional publications of such organizations as the National Resources Committee and county agricultural agencies. The documentary films, *The River* and *The Plow That Broke the Plains,* were shown, studied and discussed. As an integral part of this preliminary work, a number of field observations and studies were made. One of these field surveys was made with the local county agent of the Soil Conservation Service. This latter survey was designed to investigate the extent and types of erosion of the surrounding region and engaged the attention of the entire class for a half day. Evidences of erosion were so plentiful that a second—all day—trip was made by a portion of the class. At this time samples of the soil were taken and examined, and photographs were made of regions where the subsoil was showing, illustrating the deposition of worthless sand on lowlands, the silting and filling of drainage ditches and waterways, and the loss of the richer and lighter components of the soil through carriage to larger waterways and ultimately to the sea.

The prime aim of this preliminary work was to develop critical awareness of the problem in its local, regional, and national scope. The teacher acted as leader and counselor but the class was given, and accepted, increasing responsibility as the work progressed.

As the problem became clearer and its significance and complexity became more apparent the realization grew that an understanding of the problem sufficient for intelligent attack by individuals and groups demanded more information than the class had. It became clear that some understanding of plant life, its variety and its relations to the soil, was needed for the further study of the problem of good land use. It was also recognized that more knowledge of the formation of soil and the nature of erosion of different types of soil was necessary. Therefore the class planned and executed a series of studies designed to produce data which were needed to interpret the problems that had been seen in the preliminary investigations.

A plot of ground in the school yard was secured and set aside for experimental study. Soils of various types were examined and tested for water absorption and run-off characteristics under controlled conditions. References on soil formation were used. The study of the relationship

of plants to the soil was made through study of references and through experimentation. A hydroponics experiment was carried out which illustrated the need of green plants for certain minerals. Plant physiology was studied to determine in more detail what particular plants took from the soil, what they returned to it, what they did to enrich or build up the soil, and what they did to tear it down. Root systems were studied, not for the intellectual pleasure of knowing the distinction between a tap and fibrous root system, but in order to determine the soil holding qualities of various root systems. Study of transpiration and observation of a watershed in the region developed some understanding of the relation of forest lands to the water holding capacity of the land.

As a result of these and other studies, observations, and experiments, the students developed sufficient knowledge and skills so that they were prepared to study and understand the nature of remedial and preventive work being done by governmental and other agencies. In other words, the data developed were applied to the problems of good land use that the students had earlier clarified. Upon application, these data gave the students a critical understanding of present trends in the problems and possible solutions in general and specific terms, and an appreciation of the work being done and of the need for widespread, but critical, support of the organizations carrying on that work.

In connection with this latter phase of the work a field study was made of a Soil Conservation District and demonstration station. The plot of ground used for experimental study by the class was actually planted and cultivated in a number of ways to determine under controlled conditions the comparative advantages in specific situations of contour farming, strip cropping, and so forth. Exhibit materials annotated to depict the causes, nature, and control of erosion in the region in which they lived were prepared for the benefit of others in the school. Ultimately the students intend to write an article for newspaper publication designed to give the citizens of their community the benefits of their study.

A teacher's reaction to this brief and inadequate account of a *problem-focussed* development of student activities designed to explore intensively an urgent conservation problem will depend, of course, on his viewpoints of the values to be derived from science instruction. His reaction will depend, too, on the degree to which he recognizes and appreciates the assumptions basic to the approaches in science education which have been briefly discussed in this paper. It is likely that each approach would include much science material common to the other approaches. It will be noted, for example, that a great deal of content from plant physiology ordinarily included in a *field-covering* approach was actually included in the activities just described. But it was included, as needed, to help answer questions that were real and significant. Subsumed within such a problem framework it appears likely that facts and concepts will be longer retained, and with more meaning, because they were learned in a meaningful situation. And if our goal in science education is to develop the insights, knowledge, and skills that will enable us as a people better to solve our persistent personal and social problems, and to solve them democratically and scientifically, I believe that the growing trend to consider such problems as foci, rather than incidents in science education, is a significant one and is worthy of our serious attention.

A COMPARISON OF THE OUTCOMES OF INSTRUCTION OF THE CONVENTIONAL HIGH SCHOOL PHYSICS COURSE AND THE GENERALIZED HIGH SCHOOL SENIOR SCIENCE COURSE

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To facilitate integration of the experiences of the pupil, generalized courses based on a fusion of subjects have been introduced into the secondary school curriculum. This trend is reflected in the field of science education by the development of revised science offerings employing the method of fusion of several subject-matter areas into single broad-field courses centering around some significant activity. The generalized high school senior science course encompassing the fields of physics and chemistry and emphasizing consumership as an activity represents an attempt to carry out the purposes of integration in the school program.

An investigation was undertaken to measure and compare some of the purported outcomes of instruction of a generalized high school senior science course stressing practical applications and consumer education and a conventional high school physics course employing the lecture-demonstration method and stressing classical applications and problems. Data were obtained by the administration of two forms of one examination and one form each of nine other examinations either initially and terminally or terminally to the students enrolled in the senior science and physics classes of the Chaska High School, Chaska, Minnesota, during the academic year 1940–41.

To measure learning capacity, Forms A and B of the Terman Group Test of Mental Ability were administered to the students of the classes under observation. In addition, Form O of the Coöperative Physics Test, Noll's Scientific Attitudes Test, and a physics test designed to measure certain objectives in the field of physics common to both groups (hereafter called the Designed Physics Test) were administered at the beginning of the school year. At the end of the year these three tests were again administered. At this time students were also given a general science test, the 1941 Minnesota State Board Physics Examination, and tests of evaluation of advertising, of consumer information, of consumer applications, and of physics applications. In order to adjust the inequalities and to provide valid bases of comparison, the methods of analysis of variance and covariance were used.

It was found that the difference in means on the attitude test adjusted for inequalities of the two groups with respect to mental test scores was significantly in favor of the senior science group, while in the case of the Evaluation of Advertising Test no significant difference existed between the two groups. No significant difference was found between the adjusted means of the senior science and physics groups on the General Science Test scores when the factors of learning ability as measured by the intelligence test were taken into consideration. Likewise, no significant differences were found between the means of the senior science group and the physics group on the Consumer Information and the Consumer Applications Test scores adjusted for inequalities with respect to mental test scores.

In the case of the means on the final Designed Physics Test of the senior science and the physics group adjusted for

mental ability and initial status on the Designed Physics Test, no significant difference existed between the means.

Highly significant differences in adjusted means in favor of the physics group were found on the test scores of the Physics Form O Test, the Physics Applications Test, and the 1941 Minnesota State Board Physics Examination.

The results of this investigation are summarized as follows:

1. The generalized high school senior science course and the conventional high school physics course are both effective in bringing about significant gains in knowledge of scientific facts and information of a general nature. Gains were greater in the conventional high school physics course, probably because of the greater ability of the students enrolled in this type of course.

2. The generalized high school senior science course did not prove effective in bringing about significant gains in knowledge of specific physics materials while the conventional high school physics course proved effective in bringing about highly significant gains in knowledge and understandings of physics materials.

3. Although significant differences existed between the students of the generalized high school senior science course and the students of the conventional high school physics course on scientific attitudes as measured by the Noll's Attitudes Test, neither the generalized high school senior science course nor the conventional high school physics course proved effective in bringing about significant changes in scientific attitudes.

4. The generalized high school senior science course proved no less effective than the conventional high school physics course in the teaching of general scientific facts and principles and applications of those principles to pupils when inequalities of mental ability and previous achievement were taken into account.

5. The conventional high school physics course proved definitely superior to the generalized high school senior science course in developing in pupils understandings of specific physics materials as measured by several physics tests even after inequalities of mental ability and previous achievement were taken into consideration.

6. The generalized high school senior science course proved no more effective than the conventional high school physics course in bringing about the attainment by students of the specific consumer outcomes or objectives as measured by several tests after the factors of inequality of mental ability were considered.

THE ORIGIN OF SCIENCE EDUCATION AT THE JUNIOR HIGH SCHOOL LEVEL

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MOST junior high school science teachers have some knowledge of science education practices as they prevail in many present-day reputable junior high schools; they possess some knowledge of the recommendations made by one or more of the twentieth-century national science education committees; and they are familiar with the findings of many studies covering various phases of the teaching of science. In all likelihood they are acquainted with the proposals for science education made by the Committee of Ten, and perchance with recommendations made by other similar committees reporting on curriculum reorganization. However, few are familiar with science education practices prevalent at the junior high school level during the first century of our national existence.

Once subject matter, teaching processes, or administrative practices have been adopted, they tend to become fixed by tradition and may remain long after their appropriateness has become open to question. If the junior high school science teacher is interested in the progressive development of junior high school science education he is unlikely to allow that which is now customary to remain as it is without challenging its suitability; it devolves upon him to separate the chaff from the wheat. He can do this in the light of an examination of the contributions made by each period, with intent of retaining all the advances previously made which have present value, and eliminating all the material that has become obsolete. An examination of past science education practices should be of interest and significance to every junior high school science teacher who is attempting to adapt his work to current conceptions of educational needs. But where is the teacher to obtain this information? A search through the professional literature will not reveal a comprehensive treatment of the science movement at the junior high school level. Among many junior high school science teachers there exists a popular idea that science education at this grade level is of rather recent origin—a fallacious conception, as can be shown.

A national deliberative body made proposals for science education at the junior high school level as early as 1876 when Superintendent Harris of the St. Louis public schools read the report of the Committee on a Course of Study from Primary School to University before members of the National Education Association (1).* This same educator, in 1871, introduced an extremely well-organized science curriculum into the public schools of St. Louis which provided for instruction in all three grades now assigned to the junior high school.

In planning his science curriculum Harris first mapped out the domain of natural science so that no one province would be adopted to the neglect of others equally important; second, he ascertained what phases of the several provinces of science were suitable for popular exposition and were easily illustrated; and third, he sketched out the course by cycles—a child going through a complete cycle made acquaintance with all the provinces.

The cycle assigned to the two years preceding the first year of Harris' four-year high school was expected to generalize the ideas of the pupil so as to make the effects

* Numbers in parentheses refer to the Bibliography which concludes this article.

of the science instruction permanent. It was thought that the maturity of the pupil of this age allowed him to investigate phenomena with some degree of scientific interest. The course of instruction for these two years was to be taught in oral lessons, one hour being set apart each Wednesday afternoon for that purpose. The science materials allotted by Harris to this cycle were as follows: first year, material from physical geography, including geology, meteorology, and the study of organisms; second year, material from natural philosophy, or physics.

The first year of the high-school course was to be taught for two terms (there were four terms each year) and allowed the same amount of time each week as other required studies. (This was as it had been before 1871.) Students in the first year of high school were to study Warren's *Physical Geography*. Later this book was assigned for use at the seventh-grade level and physical geographies by Colton, Warren, and Guyot assigned to the ninth-grade level. (In the year 1874–1875 the ninth-grade course was eliminated.)

The science course was arranged "with reference to *method* rather than quantity or exhaustiveness." The teacher was admonished to be thorough on what was done rather than to attempt to cover everything outlined; every ten weeks the pupils moved on to the next quarter's work, regardless of how much or how little had been accomplished. The children were to be encouraged to describe their own experiences and reflect on them; they were to be taught to reflect upon what they saw so as to strengthen "powers of observation"; they were not to be burdened "with too many new technical phrases at a time" but on the other hand "not fall into the opposite error of using only the loose common vocabulary of ordinary life which lacks scientific precision." The teacher was never to omit showing "by a synopsis on the black-board what has been discussed in the lesson, its classification and relation."

Harris believed that in many studies the teachers were liable to become stiff and pedantic in the conduct of recitations; that the recitations were not likely to be adapted to the deepest thoughts of the best pupils, but rather to the mechanical memorizing of the poorest pupils.

> . . . But in the Natural Science lessons everything is free; the object is to draw out as much interest as possible; hence the appeal is made directly to the best pupils in the class, who are ready to communicate their own experience and ask questions. The slow pupils are interested, but it is the interest excited by novelty, and akin to wonder rather than comprehension. . . (2)

Here we have, in the early 1870's, science education at the junior high school level. Harris had many definite ideas on the teaching of science. Becoming acquainted with them would be a thought-provoking experience.

However, science education at the junior high school level did not originate in the 1870's. Physical geography, for example, had been a required subject for several years before 1871 in the first year of the St. Louis high school. Long before 1871 physical geography was offered at the junior high school level in both high schools and district schools. The first physical geography textbook was published in 1855 (3). As far as subject matter is concerned, some of the courses taught at the junior high school level during the middle decades, and earlier, might have been termed "general science" courses. Peterson's *Familiar Science* (4) was a very popular book in the schools at the middle of the century, thousands upon thousands of copies being issued. In 1858, a New York State school official conceded that although very few common-school students acquired a knowledge of the elementary subjects, except through individual genius or energy, often they got:

> . . . a smattering of much beyond—of botany, astronomy, geology, physiology, zoology,

and I know not how many other ologies—more than they can correctly spell—but *information* is a very different thing from *knowledge*. (5)

As early as 1842 Horace Mann expressed his displeasure because few Massachusetts public-school children were engaged in studying human physiology, but admitted that:

In some of the public schools . . . botany, chemistry, natural history, astronomy . . . are attended to . . . They are not extensively pursued. (6)

In 1844 Mann could say that "Human Physiology—a knowledge of the laws and conditions of Health and Life—is now becoming common in the better class of schools, throughout the State," and that "Astronomy is now taught in many of our Common Schools." (7) Reports similar to the above may be found concerning science education in other states.

But we cannot say that science education at the junior high school level originated at about the time of Horace Mann. The data show that as early as the third decade of the nineteenth century astronomy, natural history, mineralogy, natural philosophy, geology, botany, and more than likely chemistry, were being offered in some of the schools at the junior high school level. The reader may recall that one of the required subjects in the first year of the early Boston High School for Boys was "Elements of Arts and Sciences by Blair" (8); that Botany was *allowed* in the first year of the Boston High School for Girls (9); or that science was offered in the early New York High Schools (10).

Some might claim that the beginnings of science education at the junior high school level are found in the didactic writings of the early nineteenth century designed for the use and education of children by such authors as Charlotte Sanders, Mrs. Mary Robson Hughs, Maria Edgeworth, and others. Miss Edgeworth, for example, stated in the preface of her *Harry and Lucy:* "These volumes are intended for young people from the age of ten to fourteen." (11) Chapters of this work had such titles as Barometer, Portable Barometer, Hygrometer, Pump, Pump Disasters, Air Pump, Making Ice, Steam Engines, Magnifying Glasses, and Electricity. It was said that:

These volumes were intended . . . to entice young people to the study of mechanical contrivances and scientific apparatus . . . to produce careful comparison, to elicit judgment and reflection, and to suggest such combination of thought as may aid in the inventive efforts of the imaginative faculty. (12)

Some may wish to trace the origin of science education at the junior high school level to the quasi-private schools. In the third decade at William Fowle's Boston Monitorial School, where approximately one third of the seventy-five students were of junior high school age, all but four children in the school were studying geography. The school offered instruction in astronomy, mineralogy, and "natural history and natural philosophy in all their departments." Fowle has left us excellent descriptions of science education practices in his school. For example:

No suitable book on astronomy being found . . . the instructor only painted on cloth such diagrams as were necessary to illustrate the leading principles of the science, explaining them to the scholars in familiar lectures, and illustrating them in every possible way by orreries and other apparatus . . . A few lessons were given on pleasant evenings, in the open air. . .

. . . an appropriation has been made for the purchase of apparatus to illustrate the various sciences taught, particularly that of natural philosophy . . . the pupils have performed experiments with their own hands . . . From seven hundred to one thousand dollars' worth of the best apparatus has already been purchased. . .

A class in mineralogy has just commenced its operations, with ample materials. . . The minerals are spread before the class, examined, compared, and analysed. Besides this, each child is furnished with a specimen of the mineral under consideration, to form the basis of a little cabinet of her own. (13)

Fowle's school was not the only one in which science instruction was given. William Smith, at Chesire Academy in

1801, who was "firmly bent on introducing the natural sciences," gave a course of lectures on "Natural Theology," bringing in the use of apparatus to illustrate. This course was said to be entirely successful (14). A visitor to Dr. Dwight's Academy wrote that in 1790:

> . . . he gave his boys a lecture upon the different kinds of grasses; he mentioned the time of the first use of each of them in agriculture, the best methods of cultivating them, and the different kinds that were most proper for different animals. . . (15)

Charles Caldwell, born in 1772, tells of attending a North Carolina academy when he was between 12 and 14 years of age where he was taught "a few branches of science [of a] meagre concern." (16)

The reader may reason that it is time to ride at anchor and find one's bearings. Let us, however, consider one other field of inquiry. The first geography written by an American for American school children was published in 1784 by Jedidiah Morse (17), father of the inventor of the electric telegraph. By 1795 a four-book series of geography textbooks had been published of which the intermediate volumes were Morse's *Geography Made Easy* and *Elements of Geography* (18). In the preface of the latter book Morse says:

> . . . The *second* [book of the series] is the work before us, adapted to children from 8 to 14 years old, and may be usefully read by those of a more advanced age. The *third* is *Geography made Easy*, which is an abridgment of "The American Universal Geography," and is now in use in many of the Schools and Academies in the United States, adapted to the higher classes in Schools, and the lower classes in Academies. . .

These two books were widely used—eight thousand copies of *Elements of Geography* were sold in two years in the United States—and they were used at the level intended. Mrs. Lucy Lane Allen, Noah Webster, Horace Greeley, and others who attended the American district schools in the late eighteenth and early nineteenth centuries, mention their use in the higher classes of those schools (19). The Boston School Committee's Minutes for 1789 show that Morse's Geography, abridged, was to be introduced into the Reading Schools "when found expedient." (20) Fowle tells us that when he went to school, "the chief book used was an abridgment of Dr. Morse's Universal Geography." (21) Leicester Academy, Noyes' School, Mrs. Peabody's School, Hyco Academy, and other quasi-private institutions also were using Morse's geographies at the junior high school level (22).

The scope of the materials in Morse's *Elements of Geography* is well summarized in the following quotation:

> The *first* branch of this science, viz. *Astronomical Geography*, as treated in this little book, furnishes the young Pupil with such a general knowledge of the heavenly bodies, as will facilitate his acquaintance with Geography, and elevate and enlarge his views of the wisdom, power and greatness of the CREATOR.
>
> The *second* branch, called *Natural* and *Subterraneous Geography*, gives a useful and entertaining general view of the component parts of the earth, and explains many of the remarkable appearances of nature.
>
> The *third* branch, called *Political Geography*, leads the Pupil to contemplate the earth as inhabited by men, gives him a general knowledge of all its most important divisions, by conducting him in a kind of *tour* through the whole of them. (23)

The first two branches described consisted of material found in present-day science textbooks. An examination of the first fifty pages of *Elements of Geography* shows the topics treated to be the solar system—sun, planets, moon, eclipses, comets; fixed stars, constellations; the earth—figure, motions, magnitude, component parts, natural divisions; latitude and longitude; volcanoes, earthquakes; bodies on the surface of the globe, animate and inanimate; water, salt, tides, air, heat, cold, light, winds, and clouds. Even the *third* branch contains material on mountains, rivers, soil, and birds. Some explanations were singular; some were misleading.

> WATER is a compound of vital and inflammable air, in the proportion of 85 parts of the

former to 15 of the latter. Others say, water is a compound of *fire* and *ice*. . . (24)

Air is lightest when foggy; air is expanded by heat; the weight of a square inch of atmosphere on the earth's surface is 15 pounds. So far so good, but error creeps in:

> Air is the proper vehicle of *sound*, and necessary to give us the sense of hearing. Where no air is, there can be no sound. Without air we should have no music, no smell, no light, nor be able to converse with each other. All sounds, whether loud or soft, move about 13 miles a minute.

The science materials in early editions of *Geography Made Easy* were limited, for the most part, to astronomical geography and twenty-five pages on animals. Examination of later editions, however, reveals not only science material introduced from *Elements of Geography* but also material on such phenomena as the harvest moon, northern lights, magnetism, and electricity. A paragraph—there were others—on electricity mentioned:

> That lightning and the electric fluid are one and the same substance, has been proved by Dr. Franklin and others. Lightning strikes the highest and most pointed objects; rends bodies to pieces and sets them on fire; dissolves metals; and destroys animal life; in all of which it agrees with the phenomena produced by an electrical apparatus.

The data show that science materials were introduced into the schools at the junior high school level by way of Morse's geography textbooks as early as the last years of the eighteenth century. Was this the origin of science education at that level? Before answering let us consider that the data show that many colonial children of junior high school age became acquainted with the elements of science by way of (1) conversation, lectures, and writings of college graduates (particularly schoolmasters and ministers); (2) home and apprenticeship education; (3) private tutors; (4) private school instruction; and (5) writings of classical authors recommended by Latin grammar school masters for reading outside of school.

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HUMANIZING PRE-FLIGHT AERONAUTICS IN SECONDARY SCHOOLS

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MANY secondary school teachers of science, mathematics, industrial arts, and other subjects are now teaching a course in pre-flight aeronautics. In this course students encounter references to such items as Langley Field, De Havilland airplanes, Allison engines, Stromberg carburetors, Summerill tubing, Hartzell propellers, Boeing Clippers, Kellett Autogiros, the Sperry Gyropilot, and the Curtiss-Wright Aircraft Corporation. Why is a given airport called Langley Field? Which Langley is referred to and what did he do to be so honored? How does it happen that the names of Curtiss and Wright are hyphenated to form the name of one of America's great airplane companies? It seems important that such questions as those suggested not only should occur to teachers and pupils but also that they should be explored by them if the course in pre-flight aeronautics is to make a maximum contribution to the program of general education.

Certainly such a course should stress continually experiences in scientific method if it is to deserve a place in American secondary schools. But scientific method cannot be taught by memorizing principles, formulas, and other man-made abstractions. The great discoveries in aeronautics did not come about as the result of the rigorous application of mathematical formulas; these formulas are symbolic representations of discoveries made by living men. If, then, teachers of pre-flight aeronautics wish to cultivate for themselves and their pupils an insight into the real nature of aeronautical science, they must concern themselves with men, not definitions alone. In short, they must *humanize* their teaching of pre-flight aeronautics.

How are pupils and teachers to secure this living acquaintance with the methods of solving problems used by the pioneers in aeronautics? How can pre-flight aeronautics be humanized? The activities suggested in the remainder of this paper are at least potentially useful for helping young people to comprehend the failures and successes of the men and women who have contributed to man's conquest of the air. These activities have been selected so as to show the variety of materials and methods which are available to aid teachers in the humanizing of pre-flight aeronautics. However, the selection has been limited in at least two ways. First, the suggestions are concerned only with the development of aerodynes or heavier-than-air craft. Second, no consideration is accorded those scientists whose work was not primarily concerned with aeronautics, even though

their ideas find applications in this field of applied science. Thus, the contributions of Torricelli, Pascal, Boyle, Charles, Celsius, Fahrenheit, Mercator, Maury, Gilbert, Marconi, Galileo, Newton, Bernoulli, and many others are ignored in the present paper.

PROGRESS IN THE AIR

An imposing array of materials is easily accessible for a study of aeronautical progress. As part of an earlier article [1] the author suggested some types of bulletin board activities which should be helpful in this connection. Four full page plates dealing with the history of aircraft are given in *Webster's Unabridged Dictionary.* The *Encyclopaedia of Aviation* (4) * is prefaced with a section entitled "A Pictorial Representation of the Conquest of Flight." Such books as those by Black (3), Fraser (11), Johnston (15), and Smith (24) offer many suggestions for telling the history of aviation by means of bulletin board displays.

The story of man's progress in the air may be presented in the form of a pageant (16:410–417).

The history of aeronautics is available also in a film strip (28) which is accompanied by a manual describing its use.

At least three motion pictures are available to tell the story of man's conquest of the air (33, 34, 35). This general story can easily be broken down into many subtopics, some of which are suggested in the remaining sections of this paper.

MAN SPECULATES ON FLYING

As early as the thirteenth century man began to speculate on the possibilities of flight. Thus, we find in the writings of Roger Bacon (who was born in 1214) the following prediction: "An instrument may be made to fly withall if one sit in the midst of the instrument, and doe turne an engine, by which the wings, being artificially composed, may beat the ayre after the manner of a flying bird." Materials for a bulletin board display on this forward-looking English monk will be found in the *Cenco News Chats* (6). A portrait for framing is obtainable.[2]

WANTED—AN ENGINE

It took over six centuries for man to find the engine which Bacon foresaw. However, the lack of a motor did not keep man from experimenting with flying machines without motors. Two centuries after Bacon, Leonardo da Vinci drew sketches of ornithopters in his notebooks and built flying machines that would not fly. Of Leonardo's flying contraptions, it has been said: "Leonardo da Vinci needed only a practical motor. If he had had that, the airplane would have been invented centuries earlier than it was." Moreover Leonardo was the first man to conceive the idea of the parachute. Suggestive materials for a bulletin board display on Leonardo's contributions to aeronautics will be found in Fraser (11:238–243). A portrait is available.[3]

In the centuries following Leonardo, many men experimented with motorless flying machines. We have space to mention briefly only three of these pioneers: Sir George Cayley, Otto Lilienthal, and Octave Chanute. The mention of these names is sufficient to show that no country had a monopoly on aeronautical experimentation: The first man was an English-

[1] Teller, James D. "Humanizing the Teaching of Science by Using the Bulletin Board." *School Science and Mathematics,* Vol. 41, pp. 611–619, Oct., 1941.

* Numbers in parentheses refer to the Bibliography which concludes this article. Where numbers follow the colon the figures refer to page numbers.

[2] Portrait of Roger Bacon, 10 by 14 inches. Available from Pictorial Mathematics, c/o *Scripta Mathematica,* 186th Street and Amsterdam Avenue, New York, New York.

[3] Leonardo da Vinci's portrait of himself, 5½ by 8 inches. In Teller Set of Thirty Science Teachers' Collection of Pictures, Perry Pictures Company, Malden, Massachusetts. Single pictures are not available.

man, the second a German, and the third was born a Frenchman but lived in America. All three made important contributions to the development of the glider. Materials for a bulletin board display on the pioneer work of this trio will be found in Johnston (15: 181–190) and in Fraser (11: 272–292).

It was not until late in the nineteenth century that the engine which Bacon saw in his imagination became a reality. Then John Stringfellow produced an engine-driven model which was able to fly. His portrait, sketches of two of his model airplanes, and a sketch of his steam engine are to be found in Johnston (15: 209–212).

SUCCESSFUL FAILURES

If Stringfellow is to be considered as the "first successful heavier-than-air-model builder," then Samuel Pierpont Langley and Hiram Stevens Maxim must be given a large share of the credit for constructing motor driven airplanes of essentially correct design. Although their experiments were not entirely successful, they blazed the trails which others were to follow. In preparing a bulletin board display on Langley the sketches of his aerodromes in Johnston (15: 220–230) will be suggestive. A reproduction of Langley's order to John A. Brashear for an experimental airplane model, which is "probably his first large working model of a flying machine," will be found in the latter's autobiography (23: 243–244). This book also contains a portrait of Langley. Another portrait is to be found in Maitland (21: 38). Additional suggestions for a display on Langley may be gleaned from Fraser (11: 331–337), Wilson (26: 358–366) and Black (3: 41–52). A discussion of the unsuccessful experiments of Maxim will be found in Black (3: 35–39).

FROM BICYCLES TO AIRPLANES

Roger Bacon died in 1292. Six hundred years after Bacon's death, Wilbur and Orville Wright opened a shop for selling and repairing bicycles. The two bicycle mechanics took an avid interest in Lilienthal's gliding experiments, built large kites and gliders, and finally fitted an engine to one of their gliders, which was thus destined to make the first flight ever made by a power-driven controlled airplane. On December 17, 1903, the machine Bacon had seen in his imagination became a reality. However, it was not, as he had predicted, used to cause wings to beat the air after the manner of a flying bird. The Wrights had built simply a power-driven glider capable of control.

The interesting biography of the "fathers of flight" by McMahon (20) contains sixteen full page plates which may be readily detached for use as a bulletin board display. Additional suggestions for a display on the Wright Brothers will be found in Black (3: 53–72), Fraser (11: 293–326), Graham-White (13: 1–11), Johnston (15: 230–248), and Maitland (21: 10–83).

THE FATHER OF THE AILERON

Although the Wright brothers made the first flight in a power-driven controlled airplane, the perfection of the method of control they used owes much to Glenn Hammond Curtiss. While the Wrights gained lateral control by the warping of a flexible wing, Curtiss introduced the use of ailerons for this purpose. A picture comparing the two methods of control will be found in Johnston (15: 257) together with a description of the legal battle between the Wrights and Curtiss. Material for a bulletin board display on the father of the aileron will be found in Black (3: 85–91), Fraser (11: 344–348), and Maitland (21: 84–111).

Curtiss' own story (9: 37–154) of his first flights in the "June Bug" and of his early experiments with the hydroplane will be interesting reading for some students. Other students will be interested in the poet Benét's "Ballad of Glenn Curtiss" (2: 21–26).

FIVE FAMOUS DESIGNERS

Many aeronautical pioneers in addition to Curtiss had suggestions for improving the original flying machine of the Wright Brothers. As representative of these we shall mention only five—Alberto Santos-Dumont, Henri Farman, Geoffrey De Havilland, Igor Ivan Sikorsky, and Alexander de Seversky.

It was Santos-Dumont who made the first heavier-than-air flight in Europe in 1906. A brief summary of the contributions of Santos-Dumont to aeronautical design is found in Fraser (11:337–340). Henri Farman's experiences with "Gnome" engines in his biplanes are related in a book by Graham-White (13:59–73). The contributions of Geoffrey De Havilland to aeronautical design are summarized in the *Encyclopaedia of Aviation* (4:630).

Igor Sikorsky has been called "the father of large aircraft" and is renowned for his clipper ships. A portrait and biographical sketch of Sikorsky will be found in *Current Biography* for 1940 (7:734–736). A portrait and biography of another well known designer, Alexander de Seversky, is available in *Current Biography* for 1941 (8:222–223). His book (19) concerning the relation of air power to the winning of the war and the Disney film based on it are widely known.

FAMOUS FLIERS AND FLIGHTS

We have previously had occasion to refer to the books of Claude Graham-White. However, he was not only a writer but a pioneer pilot as well. His name may well begin a list of five whom we have chosen to represent some important pioneer flights. The other four include Louis Blériot, Richard Byrd, Charles Lindbergh, and Amelia Earhart.

The name of the pioneer British pilot, Claude Graham-White, has been immortalized in a ballad by Benét entitled "First Night Flight" (2:11–20). The story of his own experiences is given in his *Story of the Aeroplane* (13:74–131).

Photographs of the monoplane in which Blériot accomplished the first crossing of the English Channel in a heavier-than-air machine are given in Johnston (15:252) and Fraser (11:340–344). Graham-White (13:42–58) credits Blériot with having made the "first historic flight" and having established the "first of the flying schools."

Although Blériot flew the English Channel alone in 1909, it was not until 1927 that a solo flight over the Atlantic ocean was accomplished. For a ballad in commemoration of this famous flight, see Benét's "Lindbergh" (2:45–46). For this famous flier's own story of his life and transatlantic flight, consult *We* (18). There are forty-seven full page plates in the book which can easily be detached and used for a bulletin board display. President Coolidge's welcome to Colonel Lindbergh on his return from Paris is available on a recording (30) as are some remarks of Lindbergh himself (29). The story of Lindbergh's survey flight around the North Atlantic ocean in 1933 has been told by his wife (17).

An excellent bulletin board display on the exploits of the American aeronautical explorer, Richard Evelyn Byrd, may be prepared from the pictures in his book *Skyward* (5). A poet's interpretation of Byrd is given by Benét (2:120–131).

Certainly no woman has done more than Amelia Earhart to give women a place in aviation. It will be a thrilling experience for girls to listen to her discussion of "Woman's Place in Science" (31), and to read *The Fun of It* (10). A biography of this famous aviatrix has been written by her husband (22). The two latter books contain ample photographs for a bulletin board display on Earhart.

Volume XXVII of the *Encyclopedia Americana* has a list of important transoceanic flights and a description of the heroic exploits of members of the United States Air Corps. The *Encyclopaedia of*

Aviation has articles on flight records, pioneer flights by women, British pioneer flights, and early Canadian flights (4: 315–354, 620–622). Fraser (12), tells the story of important aeronautical flights starting with the first flight across the Atlantic in 1919. The book is illustrated with sixty-eight maps to aid in following the flights discussed. The pictorial story of some famous flights and fliers is available in the form of a film strip (27).

WINDMILL AIRPLANES

We have noted that man's first speculations on the possibilities of flight concerned aerodynes in which some of the lift and the propulsion is derived from the mechanical flapping of the wings. No successful ornithopter has yet been designed. However, experiments with two types of aircraft other than airplanes—the helicopter and gyroplane—have met with some success. The gyroplane differs from the helicopter in the fact that the lifting propeller is rotated in flight by the action of the air on its blades, rather than by the engine. Since the wings rotate freely like a windmill, the gyroplane has been called the windmill airplane.

The most successful attempt at constructing a gyroplane is perhaps the autogiro of Juan de la Cierva, a Spanish engineer. After the crash in 1919 of a three-engined bomber which he had built, Cierva's attention was turned to the limitations of the fixed wing airplane. In 1920 he developed the theory of the rotating-wing machine or autogiro. The story of the invention of the autogiro is told by Black (3: 170–174) and some scenes showing its inventor are included in the sound reel entitled *Autogiro* (32).

ENGINES AND PROPELLERS

If it is true that for a long time the invention of the airplane was delayed for the lack of a motor, it is equally true that its rapid development has been due to the perfection of its engine and propeller. This story is told in Black (3: 158–169). The history of the airplane engine to about 1911 is related in Graham-White (13: 59–73), while facts concerning the history of the more important engines developed to about 1921 will be found in Angle (1). A bulletin board display showing the evolution of Wright engines can be prepared from the materials in Angle (1: 521–524). A similar display on Curtiss engines may be prepared from the same source (1: 139–161).

AERONAUTICAL INSTRUMENTS

The development of the airplane has been facilitated not only by the perfection of its engines and propellers but also by the invention of numerous instruments to guide it in flight. The story of some of these devices is told in Black (3: 195–206). The inventions of Elmer A. Sperry, by which the gyroscope is applied to the problems of flight, are interesting in this connection. A film *The Romance of the Gyroscope* (36) is available for acquainting students with the story of the gyroscope.

A PIONEER METEOROLOGIST

Since meteorology has had an important part to play in aeronautical progress, it is fitting to include in our list of pioneers "the first man to put meteorology on a scientific basis," James Glaisher. Moreover, he was an aeronaut himself, having taken part in various balloon ascents, usually to obtain meteorological observations. Brief biographies of Glaisher are to be found in the tenth volume of the *Encyclopaedia Britannica* and in the *Encyclopaedia of Aviation* (4: 632).

COMMEMORATING ANNIVERSARIES

One type of activity that should be especially helpful in humanizing pre-flight aeronautics is the commemoration of aeronautical anniversaries. Any of the types of activities previously suggested—bulletin board displays, pageants, films, recordings, reports, dramatizations, and readings—

would be appropriate. Thus, on December 17, a bulletin board display on the Wright Brothers would serve to commemorate the anniversary of the first power-driven, man-carrying flight in a heavier-than-air craft at Kitty Hawk, North Carolina. Additional anniversaries can be selected from those given in Burge (4:161–164), Fraser (12:xv–xxxi), Hazeltine (14), and Teller (25). To facilitate the planning of the projects suggested, this paper is concluded with a calendar of the birthdays of the aeronautical pioneers mentioned, a chronology of their birthyears, and a classified bibliography of the instructional aids utilized in the activities.

CALENDAR OF AERONAUTICAL BIRTHDAYS

Feb. 4	Lindbergh
Feb. 5	Maxim
Feb. 18	Chanute
Apr. 7	Glaisher
Apr. 16	Wilbur Wright
May 21	Curtiss
May 23	Lilienthal
May 25	Sikorsky
May 26	Farman
June 7	de Seversky
July 1	Blériot
July 20	Santos-Dumont
July 24	Earhart
July 27	De Havilland
Aug. 19	Orville Wright
Aug. 21	Graham-White
Aug. 22	Langley
Sept. 21	de la Cierva
Oct. 12	Sperry
Oct. 24	Byrd
Dec. 6	Stringfellow
Dec. 27	Cayley

CHRONOLOGY OF AERONAUTICAL BIRTHYEARS

1214	Bacon
1452	da Vinci
1773	Cayley
1799	Stringfellow
1809	Glaisher
1832	Chanute
1834	Langley
1840	Maxim
1848	Lilienthal
1860	Sperry
1867	Wilbur Wright
1871	Orville Wright
1872	Blériot
1873	Santos-Dumont
1874	Farman
1878	Curtiss
1879	Graham-White
1882	De Havilland
1888	Byrd
1889	Sikorsky
1894	de Seversky
1895	de la Cierva
1898	Earhart
1902	Lindbergh

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Film Strips

27. *Famous Flights and Fliers.* (Picturol series.) 35 mm. Singleframe. Society for Visual Education, 100 E. Ohio Street, Chicago, Illinois.
28. *Historical Aircraft.* (Picturol series.) 35 mm. Singleframe. Society for Visual Education, 100 E. Ohio Street, Chicago, Illinois.

Recordings

29. *Col. Charles A. Lindbergh* (Voices from History series). One 12-inch record, one side, 4 minute program at 78 r.p.m. General Records Company, 1600 Broadway, New York, New York.
30. *Welcome to Colonel Lindbergh on his return from Paris,* June 11, 1927 (Calvin Coolidge in Cavalcade of American Presidents series). One 12-inch record, one side, 4 minute program at 78 r.p.m. RCA Manufacturing Company, Camden, New Jersey.
31. *Woman's Place in Science* (Voices from History series). One 12-inch record, two sides, 8 minute program at 78 r.p.m. General Records Company, 1600 Broadway, New York, New York.

Motion Picture Films

32. *Autogiro* (Our World in Review series). One 16 mm. sound reel in black and white, 10 minute program. Bell and Howell, 1801 Larchmont Avenue, Chicago, Illinois.
33. *Conquest of the Air.* A 45 minute program on 16 mm. sound film. Films, Inc., 330 W. 42nd Street, New York, New York.
34. *History of Aviation: Great Beginnings* (1903–1929) (Our World in Review series). One 16 mm. sound reel in black and white, 10 minute program. Bell and Howell, 1801 Larchmont Avenue, Chicago, Illinois.
35. *Sky Riders.* One 16 mm. sound reel in black and white, 10 minute program. Available from Bell and Howell, 1801 Larchmont Avenue, Chicago, Illinois.
36. *The Romance of the Gyroscope.* One 16 mm. sound reel in black and white. Sperry Gyroscope Company, Brooklyn, New York.

YOUR ALLY, THE ENGLISH TEACHER

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THE High School of Science, in The Bronx, New York City, is a boys' school set up to capitalize students' interests in science for the purpose of furthering their general education. We do not, be assured, use English literature as a tool to teach science, although the development of skill in reading does, of course, form part of both English and science courses; but we do marshal the resources of English classes, as well as those of social studies, art, science and mathematics, to enrich the students' understanding of whatever problem or topic they are studying. In the ninth year, this marshalling of materials is formally planned by a committee of teachers of the various subjects, each of whom, nevertheless, teaches his specific subject. To indicate the work done in other grades would make this discussion far too long; we limit ourselves, therefore, to a presentation in some detail of the literature work of the ninth year, in the hope that our procedures may prove suggestive to other teachers, whether they work coöperatively or alone.

Despite the name of our school, science does not form the *core* of instruction; for that reason we believe that such a coördination of studies as we have achieved is possible not only in a "high school of science," but may be worked out in any curriculum which is centered on the study of community problems. From the vast field of community problems, specific units are selected for study; the units are framed and presented coöperatively by the teachers, each working within his own subject field. "Activities" are often worked upon in each of several classes, but in general the subjects remain distinct.

Restricted as we are by traditional set-up and curriculum, by the limitations of a large city school system, by the necessity of covering units roughly equivalent to those of the junior high school ninth year, and by the requirements of the Regents' examinations at the end of the tenth grade, we have not been able to devote ourselves as much as we should wish to the study of students' individual problems. Though a little has been done in this area (we open the year with a unit called Orientation: Adjustment to High School Living), most of our units are based on the study of problems of metropolitan living. Our central aim is to enable students to understand and act upon the idea that modern society is in its achievement and in its trends ever more dependent upon coöperative efforts. We give our attention in turn to the areas of Coöperative Citizenship, Food, Health, Housing, Work, and a final unit, Man's Conquest of Time, Space and Energy (outcomes of the development of transportation and communication resulting from the application of engines and of electricity).

ORIENTATION TO HIGH SCHOOL LIFE

Our brief unit called Orientation aims to aid students to find themselves in high school, a larger school world than they have yet known. Among the major problems of new entrants into high school are the formation of proper study habits and the adjustment of personal schedules to permit adequate time both for recreation and for work. In the science classroom, students are assisted to understand by the observation of various behavior patterns of living things, the physiological basis of

habit. By an evidence-gathering technique, they are led to formulate for themselves efficient methods of developing desirable study habits. Our science-minded students are given opportunities in our "project-room laboratory" to discover new and more adult techniques for using their free time for cultural and personal development. As a background for study of what it means to enter upon a new life and to form new behavior patterns, the students, who have meanwhile begun their year's work in literature by reviewing *Tom Sawyer,* study *The Adventures of Huckleberry Finn.* Vicariously they share Huck's struggle to accept the social standards of the Widow Douglas who has adopted him and they appraise their own efforts in the light of Huck's difficulties in achieving the new controls required of him; Huck's easy falling-back into old patterns when his father recaptures him, after all his strain in taking on the new, warns them of the dangers of relapsing into habits they are trying to break. A program of free readings, of guided movie and radio experiences, emphasizes the importance, particularly to boys who have early chosen to specialize, of a balanced and widely varied program of recreations. To this personalized interpretation of literature as vicarious living, students in English classes constantly return, whether the books under consideration deal with lives of bacteriologists or of London's adventurers in the Far North. Such an approach to literature is basic: there can be no teaching of literature on the ninth-grade level that is not first and foremost an invitation to imaginative, vicarious experience. Everything else—collection of data, formation of social attitudes, and even the specific enabling techniques of the appreciation of literature (feeling for suspense and climax, recognition of truth of local color or of profound characterization)—must be superimposed upon this basic experience of literature, and care must be always taken by the teacher of English that this fundamental experience is not swamped. The teacher of literature must remain a teacher of literature.

THE UNIT ON FOOD

With this emphasis always well to the fore, the English teacher can proceed to present various types of reading to round out the later units. In the Food unit, our central aims are (1) to develop students' appreciation of the coöperation and planning that is entailed in the provision of food for a multitude of persons who either produce none for themselves or produce only specialized types of food, and (2) to offer a modicum of consumer education, extending this study beyond the area of food to include clothing and drugs. While the science class discusses the chemistry of plant growth, soil chemistry and the nutritional demands of the human body for optimum functioning, a study in English class of *Boy Life on the Prairie* (supplemented by *Captains Courageous* or by any of the vigorous works showing the life of the cowboy) offers students an opportunity to live imaginatively in the lives of those who provide our food, and thus to achieve an understanding of their problems and emotional conditioning. The films, *The River* and *The Plow That Broke the Plains,* are at once valuable as emotional "literary" experiences and as a basis for understanding the failures that occur when scientific truths are not applied for the common good. It must be stressed here that the interpretations of the books and films presented are not—must not be—warpings of the author's intent: Hamlin Garland and Kipling and Pare Lorentz doubtless intended, and intended first of all, to convey to their readers *these specific understandings,* these specific pictures of life. It will not do to fasten arbitrarily on this or on that verbal linking of a work to a unit of study; the relationship must be integral and basic. An incidental value of our unit on Food is that it offers an approach, rudimentary indeed, to an

understanding of the agrarian life which so many thinkers have considered as fundamental to American thought. For our city-bred children, such an imaginative approach, especially if it be supplemented, as in these days of war it is likely to be, by some summer farm experiences, helps to break down that barrier which keeps America a foreign country to many New Yorkers.

HEALTH STUDY IN SCIENCE AND ENGLISH CLASSES

In the Health unit, it is even simpler to present literary materials without either falsifying or distorting the author's intention. Our Health unit in the science class traces the story of man's conquest of disease—the development of the microscope as a tool of science; the rôle of bacteria in connection with disease and its cure; discoveries in the field of immunization; the possibility of applying scientific knowledge to diseases requiring the coöperation and social control of modern society; problems of self-medication and of the use of tobacco and alcohol. The rôle of the English teacher here is to guide students to the development of precision in the interpretation of factual materials. We have used *Heroes of Science* (Cottler and Jaffe) and *Microbe Hunters.* The latter is difficult for ninth-grade students to comprehend with exactness, but it has the advantage of giving them a sense of enthusiasm, of the wonder and romance of the human achievements of the scientists. The other de Kruif books and recent best-sellers emphasizing the adventure of science are popular, too, and we have used them as supplementary reading.

HOUSING AND INTERCULTURAL APPRECIATIONS

One Third of a Nation and the film, *The City,* form the foundation of our Housing study, together with Anzia Yezierska's *Fat of the Land* for the special aspect of the rôle of the immigrant in New York life. On the basis of these works, as well as of their personal experience with New York life (most of our students are from middle-class levels, and very few have themselves experienced substandard living), the students in their science classes determine what standards of ventilation, heating, and lighting are made available by our present knowledge of science, and measure against that what is acceptable in our present economic situation. An important phase of our Housing study is the problem of segregation of racial and immigrant groups. In view of the need for the development of intercultural appreciations, we pause for a time here to consider the nature of race. With *The Races of Mankind* (Benedict and Weltfish) as a textbook, the science class defines the terms race, breed, and stock, and arrives at an understanding of the implication of these terms in relation to human genetics and human cultures. It is difficult to find suitable works that illustrate the emotional significance of these implications in their impact on society. Works like *Native Son* and *Grapes of Wrath* tempt the youngsters, but are of course too strong meat emotionally for the average ninth grader. More valuable at this level are factual works like *Big Ben* (a biography based on the life of Paul Robeson), *Up from Slavery,* and *The Promised Land,* works displaying the achievements of members of groups that have met discrimination in American society. In addition, we have sometimes found a valuable educational experience in a comparison of Martin Johnson's *Cannibal Land* or Jack London's *Son of the Wolf,* as studies of life among primitive peoples, with Margaret Mead's sympathetic and revealing *Life as a Samoan Girl.* In its latter chapters, *Huckleberry Finn* offers a fascinating and convincing study of the friendliness possible between the Negro and white, even under the handicap of ignorance, a slave economy, and pre-Civil War prejudice in the South.

THE SCIENCE TEACHER AND STANDARD LITERATURE TEXTBOOKS

All of these suggestions presuppose a course planned in common by English and science teachers. What can be done, however, when the science teacher is planning alone, or with an English teacher committed to textbooks long since bought, as so often happens? Some of the traditional textbooks of the English classroom can be handled by the English teacher and the science teacher jointly, or even, if no coöperation is possible, enriched by the science teacher alone relating his work to the work of the English classroom. Thus, a science teacher might fruitfully time his study of intercultural relations to coincide with the students' reading of *Ivanhoe,* with its pictures of the conflicts of Saxon and Norman, of Christian and Jew—conflicts of language, culture and stock, but not of "race." Such a study would bring out the meanings of the terms used and apply the concepts acquired to a resolution of contemporary conflicts; and that is certainly what Scott intended should happen. For Scott found in these emotional stresses the very springs of his story—the meaning for which the parade of medieval background supplies only the occasion. He intended that the differences between Isaac and Cedric and Front-de-Boeuf, the differences in situation and character between Rebecca and Rowena, should shed light on the realities of group differences as the reader encounters them in the street.

The Odyssey can be a springboard for making real the shrinking and growing of our world as a result of exploration and invention, and the constant shift of the boundaries of the known and unknown as man advances in topographical and nautical skill. Such a study forms a parallel to the similar reorganization of our world in terms of the airplane, and lends not only emphasis but conviction to our understanding of the global character of our world.

The study of the ballad illustrates how the literature of the past reaches us across the centuries. With almost every unit, it is possible to present poems which emphasize the emotional impact of the experiences the students are investigating: the lives of the poor, of those who are discriminated against; the love of the land; the hope of the immigrant; the effort of the Negro. Let one example suffice: our students felt that a reading of "Caliban in the Coal Mines" (Louis Untermeyer) was a valuable addition to their study in science class of the materials of the earth's crust (an aspect of the Coöperative Citizenship unit).

A word of warning: this obvious sort of correlation is very easily overdone. A correlation that rests upon a verbal link is very likely indeed to give the student an impression of monotony: he is oppressed if he studies mining in science class, the mining industry in social studies, and poems or stories about miners in English (with, it is to be presumed, drawings of coal mines in art). This sort of thing is absolutely deadly; even when the subject matter is the ever-fascinating airplane, the student soon wearies and finds even the gods of the Greeks a welcome diversion. No, the linking cannot be the linking of subject matters. The only valid basis of correlated study is unity of aim, unity of basic understanding to be achieved. But if the teacher earnestly asks himself what materials he can find—literary or scientific or just human—in books or in the street, in the shop or in the museum, that will help students understand what problems of society exist in the area under study, and what has been done about them, and what is being done, the work cannot fail to be stimulating and creative. A science teacher will find it worthwhile to scrutinize the textbooks studied in the English classes in his school and to adjust his work so as to capitalize what is being done there. And if the English teacher is willing and able to make similar adjustments, the experience may be illuminating indeed.

SOME EVALUATION INSTRUMENTS FOR BIOLOGY STUDENTS

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IN CONNECTION with the teaching of ecological material in tenth-grade biology classes,[1] various evaluation instruments were devised. These included not only tests of information, but also tests of ability to interpret maps and tables, to apply information in given situations, and to arrive at reasoned judgments. In addition instruments were designed to elicit expressions of opinion about conservation and to inventory student experiences and interests. None of the evaluation instruments was standardized, although many were prepared in two presumably comparable forms. All were designed as helps to student learning rather than as hurdles for students to clear, and all were closely related to objectives set up for the direction of the teaching process.

Among the objectives for work in the area of ecology were some general concepts which could contribute to the development of perspective on the natural order. These included concepts of a balanced community and man's relation to it, of conservation as dynamic rather than as a static process, and of the relation of community succession to successful planning for the future. Certain information was considered as important to the development of such concepts; this included information about succession and climax communities, about the characteristics and location of various vegetation areas, about the history of American forests, about the relation of forests to agriculture, water control and wildlife, and about regional problems and regional planning. Among the skills deemed desirable were those of recognizing organisms, of interpreting maps, graphs and tables, and of recognizing the applicability of information.

The translation of knowledge into action was, of course, a prime goal. To this end objectives related to attitudes and overt behavior were identified. For example, an attitude of coöperation with respect to community agencies of conservation was desired; actual coöperative work with those agencies was an even more important goal. Individual acts of conservation were likewise aims of instruction, as were vocational and avocational interests related to biological resources.

Some of the evaluation instruments may merit further description. The tests concerned with the ability to reason, for example, consisted of items each of which contained a statement of opinion; a list of reasons people have for agreeing with this opinion and a list of reasons people have for disagreeing with it; and provision for agreeing or disagreeing with this opinion.

The respondents were directed to check *all* the reasons in *both* lists which they accepted as reasons for agreeing or disagreeing; then to decide whether they agreed or disagreed with the opinion to which the reasons referred; and finally to cross out either the word "agree" or the word "disagree" in the final sentence to show their considered opinion.

Some of the items from the tests of ability to reason are given here. In each instance, space was left on the test paper for the students to add any other reasons

[1] Grant, Charlotte L. "Some Techniques in the Teaching of Conservation." *School Science and Mathematics,* Vol. 43, May, 1943.

they might have, although additions were neither expected nor received.

ITEMS TO TEST REASONING ABILITY

1. Laws to protect wild animals should be enacted and enforced.

Reasons for agreeing

—— Men interfere with the balance of nature when they kill wild animals.
—— Unless wild animals are protected by law, they will soon become extinct.
—— Many people must be compelled by law to do what is right.
—— Legal protection of wild animals contributes to the education of young people.
—— By protecting wild animals, the government protects the source of income of trappers and furriers.
—— More wild animals are available for hunters' pleasure when they are protected.

Reasons for disagreeing

—— It is not necessary to protect wild animals; they can take care of themselves.
—— As many wild animals as possible should be killed, for they interfere with civilization.
—— It is foolish to attempt to protect wild animals; law-makers should attend to more important business.
—— Laws protecting wild animals interfere with the business of trappers and furriers.
—— Men should be at liberty to hunt and kill wild animals because wild animals multiply so rapidly.
—— Laws protecting wild animals interfere with sportmen's pleasure.

Considering all the reasons you have checked, do you agree or disagree with the statement: Laws to protect wild animals should be enacted and enforced.

2. Owners of forests should coöperate with agents of the United States Forest Service.

Reasons for agreeing

—— The Federal government owns vast forests and its agents know how forests can best be operated.
—— By cooperation with agents of the U. S. Forest Service, forest fires may be greatly reduced, both in number and in severity.
—— Government agents can help the forest owner get greater yields from his forests for longer periods of time.
—— The United States Forest Service is operated for the good of the nation, and the forest owner's welfare is bound up with the nation's good.
—— By cooperation with forest service agents, a forest owner can do much to prevent erosion and to protect wildlife.
—— A forest owner who cooperates with the U. S. Forest Service can help prevent floods which damage farms, towns, and cities.

Reasons for disagreeing

—— The government should not be telling people how to manage their own property.
—— The methods which are used in government forests are experimental and expensive.
—— Cooperation with forest service agents can never decrease the chief cause of waste in forests, that is, forest fires resulting from human carelessness.
—— Forest Service men suggest methods of forest management which result in decreased income for the owner of the forest.
—— The government cannot expect private owners of forests to be concerned about floods hundreds of miles away from their forests.
—— The United States Forest Service should spend the money allotted to it in managing public-owned forests, not in trying to prevent erosion or to protect wildlife.

Considering all the reasons you have checked, do you agree or disagree with the statement: Owners of forests should coöperate with agents of the United States Forest Service.

3. Farmers should coöperate with the agents of the Soil Conservation Service.

Reasons for agreeing

—— Soil conservation agents can help the farmer grow better crops.
—— By cooperation with the conservation men, the farmer can learn new ways of preventing erosion.
—— Soil conservation men can help the farmer see how he can best adjust his practices to those of the other farmers in the neighborhood.
—— The farmer's own well-being depends on the permanent welfare of the community.
—— The soil conservation agents have training which enables them to take a long-time view of a farmer's problems.
—— By cooperation with the conservation men a farmer can learn to make better use of his land.

Reasons for disagreeing

—— Soil conservation men try to get farmers to use new ways which are still experi-

mental. They may be no better than the old ways.

______ Soil conservation agents cannot know more about a farm than the farmer who owns and operates it.

______ Farming is an individual or family job; farm families are the most self-sufficient people anywhere.

______ It is not the place of the government to tell a farmer how to operate his farm.

______ The soil conservation service is not an honest use of the tax-payer's money.

______ Farming is primarily a year-by-year job; three years is as long ahead as any farmer need plan.

Considering all the reasons you have checked, do you agree or disagree with the statement: Farmers should coöperate with the agents of the Soil Conservation Service.

4. The United States government should appropriate money for the protection of forests.

Reasons for agreeing

______ Rivers must be kept in navigable condition for the transportation of war materials.

______ Power reservoirs must be kept from filling with silt in order that we may generate sufficient power for defense industries.

______ Soil erosion must be prevented in order that sufficient food may be grown for our civilian and military populations.

______ Grazing ranges must be provided in order that there will be enough meat and milk to feed our fighting forces.

______ A force of forest rangers is needed lest our vast national forests become refuges and arsenals for fifth columnists.

______ American forests are an important source of medicine and must be protected for this reason.

______ Wood products may be used as substitutes for metals and other materials needed in defense; hence forests must be protected.

______ Turpentine and other distillation products are strategic materials in war time.

Reasons for disagreeing

______ We should spend all the money we can get in manufacturing guns, tanks, ships, airplanes, and similar materials of war.

______ Immediate necessities only should be considered during the present emergency; the protection of forests is not an immediate necessity.

______ We can face the problem of controlling floods and soil erosion after we win the war.

______ Farmers and stockmen should be perfectly willing to bear any inconvenience that may result from lack of money for the protection of forests.

______ Although Americans will need to be very thrifty during the war, it is unlikely that we will need "ersatz" materials made from wood.

______ The men employed in forest conservation are needed in war work.

______ It is necessary to use the timber in the forests now, not to conserve it for an indefinite future.

______ Unless we win the war quickly, we may not care whether we have forests or not.

Considering all the reasons you have checked, do you agree or disagree with the statement: The United States government should appropriate money for the protection of forests.

5. Factories should be prevented by law from dumping their waste matter into streams.

Reasons for agreeing

______ Factory wastes dumped into rivers interfere with city water supply systems, for people cannot drink impure water.

______ Throwing factory wastes into streams decreases man's food supply, for fish cannot live in polluted waters.

______ Dumping wastes into streams interferes with the balance of nature.

______ Factories can provide other means of disposing of their wastes.

______ When factory wastes are thrown into a stream, living conditions become unhealthful for people whose homes are along the river.

______ Factory wastes upset plant succession and the development of climax communities.

Reasons for disagreeing

______ Disposing of wastes by dumping them into rivers is both cheap and efficient.

______ River water must be purified before use in a city water supply system whether or not factory wastes are thrown into it.

______ Bacteria and microscopic water animals act upon factory wastes in river water and purify the water.

______ Even if factory wastes do kill fish, "There are lots of good fish in the sea."

______ Factory wastes soon become so diluted by river water that they have practically no harmful effects.

______ Climax communities develop in spite of stream pollution, although they represent a different climax.

Considering all the reasons you have checked, do you agree or disagree with the statement: Factories should be prevented by law from dumping their waste matter into streams.

TESTS OF ABILITY TO APPLY INFORMATION

The tests of ability to apply information were essentially essay tests. Each item had three parts: a statement of information, some of which was needed for the response; a description of a situation in which some of this information could have been applied; and a question asking how the necessary information could have been used. The items which follow illustrate these tests.

Item 1.

Information

The United States produces 48 per cent of the world's corn. At the present time, corn crops cover more ground than any other crop in America. Three-fourths of our corn is consumed by pigs, cattle, horses, and poultry. Corn is a "soil-mining" crop, removing nitrogen from the soil.

Nitrogen may be put into the soil by means of farm fertilizers, commercial fertilizers, and "green manure." "Green manure" refers to crops such as beans, peas, alfalfa, or clover. On the roots of these plants live bacteria which are able to convert the nitrogen of the air—which cannot be used by plants—into a form in which plants can use it.

Plant roots hold soil in place and keep it spongy rather than compact. Spongy soil can absorb more water than compact soil. The more compact the soil is, the more likely is it that heavy rains will wash away the top layers. Heavy rains may also wash out the mineral matter in the soil. With too little rainfall, the soil may become so dry that it is easily blown away.

Situation

An Iowa farmer limited himself to growing corn on his acres, and had good crops—sometimes excellent—during most of the years from 1912 to 1927. After this he had much less success and was unable to make his farm pay. Conditions went from bad to worse, until in 1937 the farm looked like a desert, and the farmer abandoned it.

Question

What could the farmer whose plight is described have done to save his farm? Show how each suggestion you make is based upon information in the section above.

Item 2.

Information

Every plant needs nutrients which its roots obtain from the soil, but different kinds of plants need different amounts of the various nutrients. Similarly, every plant needs water which its roots obtain from the soil, but different kinds of plants need different quantities of water. Plant roots hold soil in place, and keep it from becoming compact. Certain soils are held best by roots of trees and others by roots of grasses. If there are no roots to hold the soil, it may be washed away during heavy rains or, if it is dry, it may be blown away.

In the grassland areas known as the Great Plains, rainfall, which is not abundant, occurs chiefly in spring and early summer. The rain seldom penetrates more than two feet into the soil before it is used up by the grasses. Little, if any, moisture is stored from year to year, and the subsoil is always dry. Humidity in the Great Plains is low, and the rate of evaporation is high.

Wheat is a member of the grass family. It is adapted to a wider range of climatic conditions than any other crop except, perhaps, barley. The important wheat-growing regions are all in the temperate zones where the annual rainfall is between fifteen and thirty-five inches. The United States produces more than one-seventh of the world's wheat, but it has about the lowest yield per acre of any country in the world.

Situation

During the last war and the years following the war, farmers in the Great Plains region grew wheat, more wheat, and only wheat. Demand was great; crops were good; prices were high. As the years went by, however, yields became poorer and poorer, until in 1934 there were many farms on which wheat would no longer grow. Wells and streams dried up. Many farm families were on the verge of starvation. Family after family abandoned their farms and began a migration westward, knowing neither whither to go nor what to do.

Question

What might have been done to save the farm families from abandoning their homes? Show how each suggestion you make is based upon information given in the section above.

Item 3.

Information

The larvae of gypsy moths are destructive to forest trees such as oaks, willows, and white pines. During the course of a summer, each female moth deposits an egg mass containing as many as 500 eggs. The egg masses remain attached to some part of a tree until the following spring, when the eggs hatch, and the larvae emerge to feed upon leaves.

Female gypsy moths have large, heavy abdomens. Although they have wings, they are unable to fly.

Situation

An oak woods has become infested with gypsy moths.

Question

How may these insects be controlled? Give several suggestions, showing how each suggestion is based upon information above.

Item 4.

Information

The eastern tent caterpillar is destructive to forest trees such as the walnut, the willow, and the wild cherry. The tent caterpillar is actually the larva of a moth. Adult females lay their eggs in masses on twigs. The egg masses remain attached to the branches during the winter. In the spring the eggs hatch, and hairy caterpillars emerge. Because they are hairy, these larvae are not bothered by many birds, but cuckoos, blue jays, crows, orioles, and yellow warblers will eat them.

As soon as they are hatched, the caterpillars spin a silken tent between branches of the tree. They crawl out of the tent during the day to eat the leaves around them; at night they retire to the shelter of the tent.

Situation

A woods consisting primarily of walnut trees has become infested with tent caterpillars.

Question

How may the tent caterpillars be controlled? Give several suggestions. Show how each suggestion you make is based upon information.

USING THE TEST ITEMS

One purpose for which the items recorded in these pages have been used is that of diagnosing student strengths and weaknesses. For example, one teacher found that in responding to the item "Farmers should coöperate with agents of the Soil Conservation Service," many students gave evidence of a desire to protect the individual farmer, but few, if any, indicated that they considered the individual's problems in relation to those of the community as a whole. Having made this diagnosis, the teacher attempted to provide experiences for the class members which would lead them to develop a broader attitude toward conservation.

Again, the test items have been used as instructional aids. In discussing the controversial issues which are raised in the items, students have found it imperative to weigh facts, consider evidence, and advocate action. Some students, at least, who at first were inclined to mention as solutions to problems almost any practices which they had heard described as "good," learned to make suggestions appropriate to the situations described.

Of course the test items have also been used to measure the effectiveness of instruction. When this was done, some items were used before teaching and some after teaching, care being taken to match the items as exactly as possible. Matching could be sufficiently well done to afford some justification for assuming reliability.

Evaluation involves diagnosis, instruction, and measurement of teaching effectiveness. It is a means of determining progress toward objectives. Evaluation instruments must, therefore, be related to the objectives of teacher and class; only so are they useful means of education.

BOOK REVIEWS

REED, ALBERT A. *Radio Education Pioneering in the Mid-West.* Boston: Meador Publishing Company, 1943. 128 p. $2.00.

The author is Director-Emeritus of the University of Nebraska Extension Division, and has had a "grand-stand" seat in observing the use of the radio as an educational tool in his own and the neighboring states of Iowa, Kansas, Minnesota, Missouri, North Dakota and South Dakota. Experiences in radio education in these states are described in this treatise.

—C.M.P.

NEVIN, CHARLES M. *Principles of Structural Geology.* New York: John Wiley and Sons, Inc., 1942. 320 p. $3.50.

This textbook is especially outstanding for its numerous, splendid illustrations, and pertinent photographs. These add greatly to the understanding of the textual material which is well-selected. Geography teachers interested in elements of geography and physical geography will find this one of the best books available on structural geology.

—C.M.P.

ROBESON, FRANK L. *Physics.* New York: The Macmillan Company, 1942. 819 p. $4.50.

In this text the author sets up for himself the ambitious ideal that "it should be possible to have a textbook in physics in which the subject matter was presented in such a clear and orderly fashion that it would not be necessary for the teacher to explain the text, and that in consequence his time in the classroom could be devoted to demonstrations, discussions, and the solution of problems. The present volume is an attempt to achieve that ideal." The reviewer seriously doubts that even this good book can attain that ideal in the usual college physics course. Certainly the author has strived to present his subject matter most clearly, but a knowledge of elementary college mathematics is assumed. Unless the students are unusually good or have a fairly good mathematical background much explanation will be necessary for the classes using this book. The author is Professor of Physics at Virginia Polytechnic Institute.

—C.M.P.

POLLARD, ERNEST, AND DAVIDSON, WILLIAM L., JR. *Applied Nuclear Physics.* New York: John Wiley and Sons, Inc., 1942. 249 p. $3.00.

Few, if any, subjects in science have been studied with more sustained interest than the transmutation of the elements. Although the goal of the alchemists, it was not until Lord Rutherford's experiments two decades ago that success was attained. Transmutation is essentially linked with the atomic nucleus. The discovery of artificial radioactivity has placed in the hands of chemists, biologists and medical research workers the means of studying "tagged" atoms, which renders possible experiments that could not have been contemplated a short time ago.

The technical aspects rather than the theoretical are emphasized in this book. The essential facts and methods of artificial radioactivity and transmutation are presented. This treatise would serve admirably for a text in a course in atomic structure, or as an excellent reference for persons desiring accurate information on nuclear transmutation.

—C.M.P.

WYLIE, C. C. *Astronomy, Maps, and Weather.* New York: Harper and Brothers, 1942. 449 p. $3.00.

This book with novel title is intended for the pre-aviation training course. It has a dual purpose—to present certain fundamental principles in certain fields of science and to provide basic information for specific applications. The volume consists of four rather distinct parts. The first six chapters are devoted to discussions of the celestial sphere, the constellations, telescopes, and the earth; the second part, consisting of four chapters, discusses weather and weather forecasting; the third part consists of three chapters on maps, time and celestial navigation; and the final eight chapters are on astronomy.

Altogether Dr. Wylie has presented a most readable and excellent text. Especially are the parts on astronomy unusually good. Few if any other authors have done a better job. The treatment on weather is excellent but brief. It would seem desirable to supplement greatly the weather material here presented if one were teaching a course in pre-aviation training.

This would be an excellent text for the astronomy and weather phases of physical science survey courses. High school science teachers and lay readers will find this an excellent treatise on astronomy and weather.

—C.M.P.

DUNCAN, JOHN CHARLES. *Essentials of Astronomy.* New York: Harper and Brothers, 1942. 181 p. $1.85.

Essentials of Astronomy is a simple and nontechnical presentation of the fundamentals of astronomy. There are chapters on: (1) "The Appearance of the Sky," (2) "Appearances Interpreted," (3) "Gravitation," (4) "Light," (5) "The Sun's Attendants," (6) "The Structure and Action in the Universe," (7) "The Sun and Other Stars." There are eight pages of star maps and nearly one hundred illustrations.

Altogether this is a quite readable treatise and would serve excellently as the astronomy reference in a survey course in physical science.

—C.M.P.

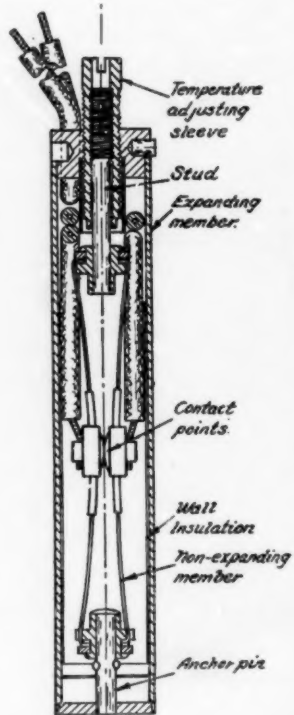
CARTRIDGE THERMOSWITCH

A NEW principle of operation distinguishes a line of thermo regulators offered by the Chicago Apparatus Company. The thermosensitive element is in the form of a closed shell, the expansion and contraction of which is multiplied mechanically by about twenty times. The contacts are mounted on a biconcave compression member of thermally inert metal which presses them firmly together while they are closed. When the outer shell is expanded by heat, the contacts are pulled apart slowly and forcibly at a predetermined setting. The slow, strong break is definite with minute changes of temperature (20 x the thermosensitive change) and the result is complete elimination of vibration or chatter. A careful examination of the drawing shown here will explain, better than many words, just how it operates.

The contacts are permanently sealed within the outer shell completely eliminating trouble due to dust, dirt, moisture and tampering. Because the sensitive element is completely exposed to the medium being controlled there is no thermal lag whatever. Adjustment for different temperatures is made by varying the length of the compression member by means of the temperature adjusting sleeve.

The basic cartridge measures 3 11/16″ x 5/8″ diameter. It may be had in several different mountings, as well as the cartridge alone, with regular I.P. fittings and also as a complete portable unit with separable electrical connector and with a knob and graduated dial.

The temperature range that can be controlled is from minus 50 to 400 or 600° F. to a differential of only 1/10°. They are dependable and long lived and their cost is very reasonable, in fact, about half the cost of the lowest priced bimetallic regulator previously available. There are two types of this switch available: one opens the contacts on *increase* in temperature, and the other opens the contacts on *decrease* in temperature.



CARTRIDGE THERMOSWITCH

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